PAIRED WATERSHED ANALYSIS TO EVALUATE PHOSPHORUS IN SPAVINAW AND BEATY CREEKS, OKLAHOMA

By

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INTRODUCTION

Background

In 1922, to meet expanding demands for municipal water supplies, the City of Tulsa, Oklahoma proposed a public waterworks project that would impound Spavinaw Creek, a watershed sixty miles to the east - northeast of Tulsa. The impoundment created Spavinaw Lake, which would have 32,000,000 cubic meters of water storage and could supply 100,000,000 liters of water per day through an enclosed aqueduct to a municipal water treatment plant. In 1954, another reservoir was built to increase the capacity of the system. This reservoir, Lake Eucha, was constructed four miles upstream from Spavinaw Lake (Blackstock, 2003).

Today, Lakes Eucha and Spavinaw, on Spavinaw Creek, supply over half of the drinking water for the cities of metropolitan and suburban Tulsa. Due to the amount of excess nutrients supplied from the watershed, excess algae growth has degraded the water quality of the lakes. While nitrogen (N) is a concern, phosphorous (P) is the primary limiting nutrient and is considered the greatest danger to water quality (Storm et al., 2001; OCC 1997). Of the 48,000 kg/yr of phosphorous entering Lake Eucha, 69% comes from runoff from poultry litter application as fertilizer to permanent pastures and row crops in the watershed (Storm et al., 2002). Poultry production is the principal industry in the basin, with over 2,000 poultry houses which produce an estimated 85 million birds annually and approximately 91,700 tons of poultry litter each year. Most of the poultry litter is applied to permanent pastures in the basin (Storm et al., 2002).

The implementation and effectiveness of best management practices (BMPs) for manure management is critical to water quality protection from N and P in surface runoff from land application of poultry litter. This nutrient pollution of N and P can lead to excessive algal growth and eutrophication in streams and lakes, which in turn degrades the water resource for uses such as boating, swimming, fishing, and as a source of drinking water. By limiting the loss of these nutrients to receiving water bodies, excess algal growth can be controlled to prevent or reduce eutrophication (Vollenweider 1968).

Examples of BMPs that can be utilized in the basin include riparian management/improvement, pasture planting, nutrient management, offsite watering for cattle, and construction of heavy use areas for animal feeding (OCC 2005). The effectiveness of BMPs at reducing the amount of nutrients entering the stream is dependent upon many complex factors that are site specific. This provided the need to evaluate recently implemented BMPs in sensitive watersheds, such as the Eucha/Spavinaw basin.

The Oklahoma Conservation Commission (OCC) began a project in 1999 to evaluate implemented BMPs using a paired watershed study design with one year calibration and treatment periods. This project looked to build upon this existing research in Beaty Creek and expand the analysis to include Spavinaw Creek, using two year calibration and treatment periods.

Purpose of Study and Objectives

The purpose of this study was to determine whether a relationship exists between the implementation of BMPs and reduction in poultry litter application, and total P (TP) load in the Spavinaw Creek basin. A cause and effect link between BMPs and water quality cannot be shown as all the factors that affect the response to the treatment are not controlled. However, water quality could be correlated to the effect of changes in land use, and could support an association relationship.

If association was supported, attempts could be made to quantify reductions in TP loading attributable to BMP implementation and reduced litter application in the Spavinaw Creek basin. A paired watershed approach was employed to account for climatic variability. With locations shown in Figure 1, Beaty Creek was first paired with Little Saline Creek (control) to evaluate the effects of implemented BMPs and reduction in poultry litter application. Next, Spavinaw Creek was paired with Little Saline Creek (control) to evaluate the effect of reducing litter application only. Finally, Beaty Creek was paired with Spavinaw Creek to evaluate the effects of only the implemented best management practices. These results allowed a comparison between the impact of reduced litter application and BMP implementation.

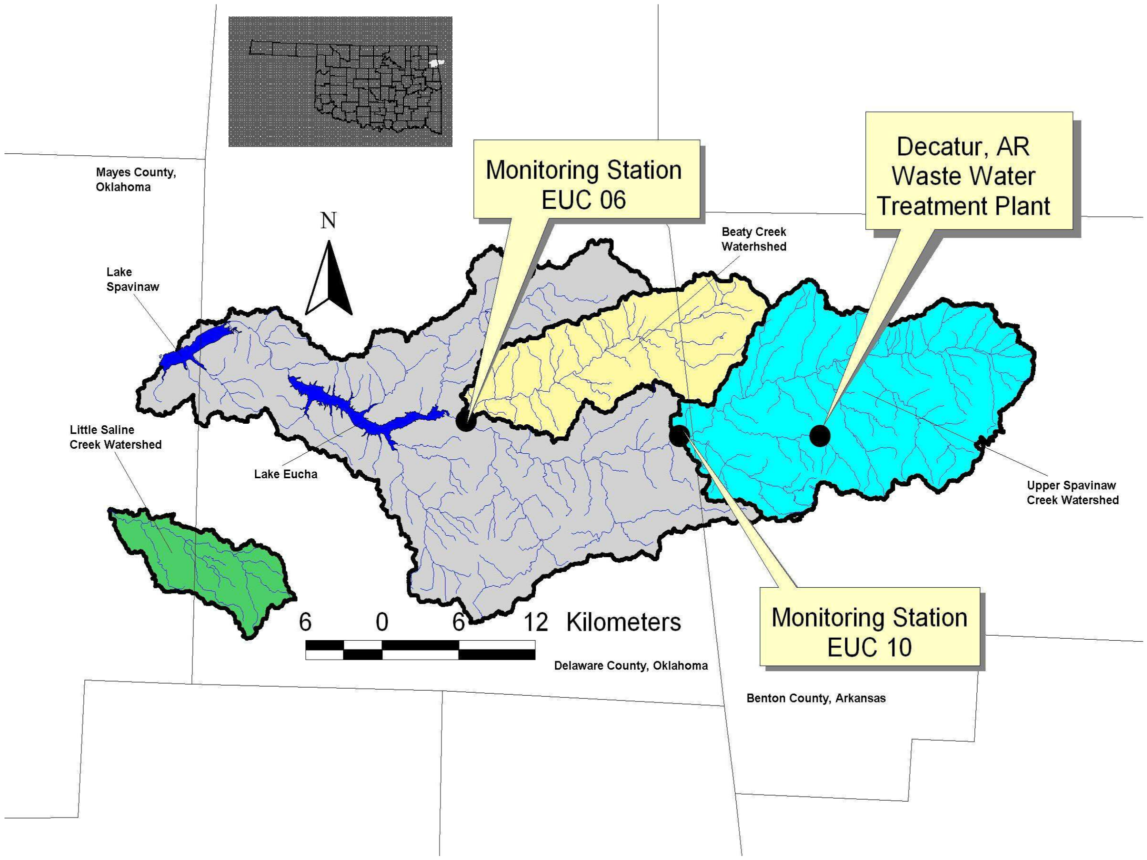

Figure 1. Upper Spavinaw Creek, Beaty Creek, and Little Saline Creek watersheds used in this study, monitoring sites EUC06 and EUC10, and the City of Decatur, AR waste water treatment plant.

The specific objectives of my research were to:

1. Determine if BMP implementation and reduced poultry litter application reduced P loads to Beaty Creek during the period 1999 – 2005.

A) H_0: BMPs and reduction of poultry litter application reduced P loads to Beaty Creek.

H_1: BMPs and reduction of poultry litter application did not reduce P loads to Beaty Creek.

2. Determine if reduction of poultry litter application reduced P loads to Spavinaw Creek during the period 1999 – 2005.

   A) H_0: Reduction of poultry litter application reduced P loads to Spavinaw Creek.

   H_1: Reduction of poultry litter application did not reduce P loads to Spavinaw Creek.

3. Determine if BMPs reduced P loads without the influence of reduced poultry litter application during the period 1999 – 2005.

   A) H_0: BMPs reduced P loads without the influence of reduced poultry litter application.

   H_1: BMPs did not reduce P loads without the influence of reduced poultry litter application.

CHAPTER 2

LITERATURE REVIEW

Background

In 1997 the City of Tulsa began a water quality study of the Eucha-Spavinaw Lake system. The study found that both lakes were nutrient enriched and displayed high and excessive levels of algal production (OCC 1997). At one point during the study the concentration of geosmin, an algal byproduct that causes taste and odor problems, measured over 2,000 ppt, which is well above the human detection concentration of four ppt (Blackstock 2003). These geosmin levels required the City of Tulsa to suspend use of Spavinaw Lake for the duration of the taste and odor event. When the water became usable again, annual treatment costs for taste and odor control soared from around $25,000 in 1996 to over $775,000 in 1999 (Blackstock 2003). Treatment costs have since declined due to the installation of granular activated carbon filters at the city's treatment plant at a cost of $761,000 in 1999 and 2000 (Blackstock 2003).

On December 10, 2001 the City of Tulsa filed suit against six poultry integrators and the City of Decatur, Arkansas, in Federal Court for polluting the City's water resource (U.S. District Court, Northern District of Oklahoma, Case No. 01 CV 0900EAC). The complaint claimed that the defendants committed acts in the course of the growth in their business, which caused damages to the City of Tulsa water supply. In 2003 an out-of-court settlement resulted in a

$7,500,000 payment by the poultry industry and a court-imposed restriction on the use of poultry litter as fertilizer in the Eucha-Spavinaw basin. During 2003 a full moratorium on litter application in the basin was required, and in 2004 the court order stipulated that at least 1/3 of the poultry litter must be transported and used outside the basin. Also, those who applied poultry litter were required to have a nutrient management plan written by a watershed team supervised by the court-appointed special master. The settlement agreement specified that these restrictions would continue until at least 2008 (OCC 2005).

These events offered a unique opportunity to monitor and analyze the changes in water quality resulting from a sudden reduction in poultry litter application and development of nutrient management plans at a basin-wide level. The City of Tulsa, a court-appointed special master, U.S. Geological Survey (USGS), and others collected considerable data on the basin that were used to evaluate these effects on water quality.

Litter Application

Poultry litter is a low cost fertilizer that when applied properly returns nutrients and organic matter to the soil, building soil fertility and quality. Land application of poultry litter returns N, P, and K as well as other micronutrients to the soil; however the nutrient content of poultry litter varies and is dependent on the type and age of the birds and the moisture content of the litter (Zhang et al).

In order to minimize the loss of nutrients, poultry litter should not be applied to soil beyond the limits of the growing crop's nutrient needs and should be applied as near to the growing season as possible. Since poultry litter has an average N:P ratio of 3:1, and major grain and hay crops use N and P at a ratio of 8:1, excess P is supplied when poultry litter alone is used to meet all the N needs of the crop (Gilbertson et al., 1979). Pastures do offer some flexibility in application timing; however fall and winter application is not desirable for warm season grasses because the nutrients are not used and the litter must remain on the soil surface for months before the growing seasons begins.

Eutrophication and Nutrient Pollution

Unlike N, P is relatively immobile in soil and must first be transported to a surface water environment to have an environmental impact. P enters receiving waters via transport in eroded soil as sediment-bound P, eroded organic matter, or in surface and subsurface runoff as soluble inorganic and organic P. Soils containing P levels that greatly exceed the agronomic potential of crops may require years, decades, or even centuries to return to levels that are crop limiting. Environmental concerns include the capacity of such soils to adsorb new P and the amount of P loss from these soils from erosion, runoff, drainage, or leaching to ground water (Daniel et al., 1994).

The major pathways that P is transported by water are overland flow, matrix flow, preferential flow, interflow, and land drainage structures such as ditches, tiles, and animal tunnels. Precipitation provides the major source of energy for transport through its effect on soil erosion, overland and subsurface flows (Sharpley et al., 1992).

The loss of soil P occurs in dissolved and sediment-bound or particulate forms. Dissolved P is typically comprised mostly of ortho-phosphate, which is immediately available for algal uptake. Sediment-bound P includes P sorbed by soil particles and particulate organic matter eroded during surface runoff. Runoff from properly managed grasses or pasture systems typically carry little sediment and are dominated by dissolved P (Daniel et al., 1994; Sharpley et al., 1992).

Paired Watershed Studies

The foundation of the paired watershed approach is that there is a quantifiable relationship between two or more watersheds for a parameter of interest, and that this relationship remains the same until major changes occur in one of the watersheds. It is not the actual water quality of runoff from the control or treatment watersheds that are the issue, but rather that the relationship between paired observations remains the same through time, except for the effects of changing cultural practices, such as the implementation of BMPs (USEPA 1993).

The paired watershed approach, implemented statistically with linear regression analysis, is designed to detect smaller changes over shorter time periods than the single watershed approach. Since many monitoring studies have a poor likelihood of detecting a cumulative effect, the statistical power of detecting a change is an important consideration (USEPA 1993; USEPA 1997b).

Many paired watershed studies have been completed since the inception of the concept in the 1950's. The history of the use of paired watershed studies to evaluate the effect of forestry practices on water yield, stream flow, and water quality is long and varied (Reinhart 1967; Bishop et al., 2005). Paired watershed studies have also been used extensively in investigating the effects of forestry practices on fish and aquatic habitat (Skaugset 2005).

Paired watershed studies have also been employed in the past few decades as a way to evaluate best management practice effects in agricultural settings (Spooner et al., 1985). In 1993 the U.S. EPA adopted a uniform paired watershed effects study design that gave researchers and watershed managers a template for studies with this approach. Paired watershed studies are considered most appropriate for documenting BMP effects within a relatively short time period (Spooner et al., 1985). If properly implemented, this method provides reliable results and is perhaps the most effective design for monitoring BMP program effectiveness (Coffey et al., 1993). Only a few studies, such as Galeone (2000), have monitored BMP treatment effects on a small watershed scale. The advantage of this scale is the ability to evaluate an area large enough to capture P transport processes, yet small enough to focus on nutrient loads from a single farm and the management practices adopted at that scale. Bishop et al. (2005) found a 43% reduction in TP load using the paired design on a 160 ha watershed in upstate New York. This study evaluated BMPs implemented on a single dairy farm, and the changes in farm management practices clearly produced a decrease in TP load.

Large basin scale studies have relied primarily on modeling (Storm et al., 2002) or on direct sampling of stream water quality (Meals 2001; McCoy et al., 2003; Udawatta et al., 2002). McCoy et al. (2003) conducted a study in Wicomico County, Maryland to demonstrate the effects of nutrient management and reduced poultry litter application on water quality. A 1,779 acre treatment watershed and a 2,342 acre control watershed were monitored from 1994 to 1998 as the calibration period and 1998 to 2001 as the treatment period. The treatment in 1998 through 2001 was primarily the transportation of all poultry litter from the treatment watershed, while replacing it with inorganic fertilizers. One hundred percent of the farming operations in the watershed participated. With only the reduction of poultry litter application this study reported a 98% decrease in TP load.

Table 1 summarizes seven selected paired watershed studies that have been completed. This summary illustrates that the paired technique can be used on a range of watersheds that have differing land uses, sizes, and pollutants of interest. It also shows that calibration and treatment periods can vary in length and time between the periods. Finally, the table illustrates that reductions can be found in relatively short time periods, which might not be possible without using the paired watershed approach.

Table 1. Summary of Selected Paired Watershed Studies on Nonpoint Source Pollution.

Watershed	**Area (ha)**	**Land Use**	**Stream Parameter**	**Pollutant Source**	**Calibration Length**	**Treatment Length**	**Study Outcome**	**Land Treatment**
Beaty Creek, OK	15,375	Forest 51%, Pasture 43%	Phosphorus	Poultry Litter	1999	2004	14% reduction	BMPs *, reduced poultry litter application
Cannonsville Reservoir Basin, NY	160	Forest 53%, Pasture 38%	Dissolved Phosphorus	Dairy Farm	6/1993 - 5/1995	6/1995 - 10/1996	43% reduction	BMPs
Peacheater Creek, OK	6,560	Forest 36%, Pasture 54%	Phosphorus	Poultry Litter	12/1995 - 8/1998	1/2002 – 1/2004	Not yet determined	BMPs
South Fork Green Run, MD	720	Cropland 54%, Woodland 46%	Phosphorus	Poultry Litter	1994 - 1998	1998 -2001	98% P reduction	BMPs, reduced poultry litter application, cover crops
South Fork Hinkle Creek, OR	1,060	Forest	Suspended Sediment	Clear Cut Forestry	1991 - 2001	2001 - present	Not yet determined	BMPs, reforestation
Walnut Creek, IA	5,220	Row crop 69 to 61%, Grass 27 to 30%	Nitrogen	Commercial Fertilizer to Row Crops	1992	2000	28.3% N reduction	BMPs
Agroforest Watershed, Greenly Research Center, MO	4	No-till Row Crop	Phosphorus	Commercial Fertilizer to Row Crops	1991 - 1996	1997 -2000	17% P reduction	Ag crops interspersed with trees

* BMPs considered to be any management practice that is recommended in that geographic area for reducing the pollutant of interest.

CHAPTER 3

MATERIALS AND METHODS

Study Site Selection and Characteristics

The Beaty and Spavinaw Creeks basin covers 93,000 ha in Delaware County, Oklahoma and Benton County, Arkansas. Located in the Ozark Highlands and the Central Irregular Plains Ecoregions, the basin has an average annual precipitation of approximately 115 centimeters. The topography is karst, with exposed limestone in some areas. Soils are mainly ultisols, and are typically thin and highly permeable. Land cover is primarily pasture and forest. Forest is mainly deciduous, and occupies 51% of the area while pasture occupies 43%. Other land cover is 2.7% row crop, 1.9% water, 1.5% urban, and 0.3% brushy rangeland (Storm et al., 2001, 2002).

Karst is a distinctive topography in which the landscape is largely shaped by the dissolving action of water on carbonate bedrock. This geological process, occurring over many thousands of years, results in unusual surface and subsurface features ranging from sinkholes, vertical shafts, losing streams, and springs, to complex underground drainage systems and caves (Neill 2004). The karst topography greatly complicates the hydrology of the Beaty and Spavinaw Creeks basin with many natural springs and losing streams throughout the basin. A spring is a resurgence of ground water that usually occurs on a valley floor and flows into a stream, while a losing stream is one with a bed that allows water to flow directly into the ground water system. There are many cherty gravel-bottomed losing streams in the Ozarks. This may complicate nutrient flow as water that fluctuates between ground and surface water may have different nutrient concentrations while the flow stays relatively stable. Relatively little information is available on subsurface transport of P in karst topography, but as with surface runoff, the potential for nutrient losses in subsurface drainage appears to increase with increasing soil P concentrations (Heckrath et al., 1995).

Little Saline Creek was chosen as the control watershed by the Oklahoma Conservation Commission (OCC) from a previous study, and thus it was also adopted in this study due to it’s proximity to the Beaty and Spavinaw Creeks basin. Due to their proximity, it was assumed that both basins experienced similar climatic and hydrologic events. The proximity also supported an assumption that the basins had similar topography, land cover, and cultural practices (USEPA 1993). Little Saline Creek was also chosen as no major land use changes had occurred during the study period, which was of the utmost importance for paired watershed analysis.

Best Management Practices

Since 1999, BMPs have been implemented throughout the Beaty Creek basin by the OCC under the USEPA Section 319 program. These practices focused on reducing water quality impacts of animal waste and cattle grazing, which had the highest potential to contribute to TP loads. Practices included riparian management, buffer and filter strips, streambank stabilization, animal waste storage facilities, pasture establishment and management, heavy use areas for cattle production and installation of septic systems (OCC 2005). Specifically, the OCC implemented BMPs that included protecting 330 acres of riparian area by installing 34 off-site watering facilities and 9.4 miles of fencing. They improved 7,135 acres of pastures in the watershed through prescribed grazing strategies, and planted 1,683 acres of pasture that was formerly either cropland or poorly vegetated pasture. Also, they began the implementation and use of nutrient management plans (OCC 2005).

Other BMPs were implemented in the Beaty and Spavinaw Creeks basin by the Natural Resource Conservation Service (NRCS) EQIP program. The NRCS only tracked dollars spent on BMP implementation on a county level and not a watershed level, so quantifying the amount spent from this program in the Beaty and Spavinaw Creeks basin was very difficult. Thus, these NRCS BMPs must be included as practices that contributed to any reduction in TP in Beaty and Spavinaw Creeks.

The Decatur, AR Waste Water Treatment Plant (WWTP) was the only significant point source in the basin. Physical improvements and changes in management to the Decatur, AR WWTP since 2003 have reduced the amount of TP that flowed into Spavinaw Creek. The point source must be accounted for to quantify the amount of TP coming from nonpoint sources.

Methods

Paired Watershed Study Design

A paired watershed study is an approach that requires a minimum of two watersheds, a control and a treatment watershed, and two periods of study, a calibration and a treatment period. The control watershed has the same management practices throughout the duration of the study (calibration and treatment periods), while the treatment watershed undergoes a change in management at some point during the study. During the calibration period baseline data are collected. During the treatment period, one watershed changes its management regime, while the control watershed remains in the original management (Table 2).

Table 2. Schedule of BMP implementation for the paired watershed approach.

Period	**Watershed**		
	Little Saline	Beaty	Spavinaw
Calibration	No New BMPs	No New BMPs	No New BMPs
Treatment	No New BMPs	OCC BMPs NRCS BMPs	NRCS BMPs

The basis of the paired watershed approach is that there is a quantifiable relationship between paired water quality data for the two watersheds, and that this relationship is valid until a change is made in one of the watersheds. At that time, the treatment period, a new relationship will exist. This does not require that the quality of runoff be statistically the same for the two watersheds, but rather that the relationship between paired observations of water quality remains the same over time except for the influence of the change (USEPA 1997a).

Often an analysis of paired observations indicates that the water quality is different between the paired watersheds. This difference further substantiates the need to use a paired watershed approach because the technique does not assume that the two watersheds are the same; it does assume that the two watersheds respond in a predictable manner together due to experiencing similar weather and precipitation events. By accounting for weather and other environmental factors, statistically the paired watershed approach can be successful at documenting water quality improvements (USEPA 1993; USEPA 1997a).

At the end of the treatment period the significance of the BMP implementation effect was determined using an analysis of covariance (ANCOVA). The analysis was a series of steps determining: a) the significance of the treatment regression equation, b) the significance of the overall regression which combines the calibration and treatment period data, c) the difference between the slopes of the calibration and treatment regressions, and d) the difference between the intercepts of the calibration and treatment regressions (USEPA 1993; USEPA 1997b).

Precipitation was assumed to be similar since the two basins were close in proximity and had similar areas (Beaty Creek 15,555 ha, Upper Spavinaw Creek 31,170 ha, Little Saline Creek 6,170 ha). Basin hydrology depends not only on basin size, but also on bedrock and surficial geology, slope, soils, land cover, and land use (Smith 2004). Little Saline Creek watershed was chosen by OCC as the control as it is proximal to Beaty and Spavinaw Creeks and lies in a similar geologic region that exhibits many of the same characteristics as the Spavinaw Creek basin. Beaty and Spavinaw Creeks had essentially the same geologic features, so the difference in areas was not as great a concern when comparing data (Smith 2004). To evaluate the assumption of similar precipitation between basins, data from the two closest weather stations were compared (Appendix A). Although there were differences in precipitation during both the calibration and treatment periods, this assumption was required for this approach. Due to the location of these weather stations, it was difficult to accurately assess these actual differences.

Due to the majority of BMPs being implemented during the years 2001 to 2003, the two year period of September 1999 to September 2001 was selected as the calibration period. The two year interval of September 2003 to September 2005 was selected for the treatment period as this was the most current data available. These calibration and treatment periods, while short compared to many studies, still allowed a statistically valid comparison. One major concern with the relatively short calibration and treatment periods was that the response time for the BMPs to start to have a significant effect might not yet have taken its full effect. The system may have needed to fully “flush” sediment and nutrients from the watershed from historical activities. There may not have been adequate time for this to occur, which could have resulted in inaccurate conclusions (USEPA 1997a).

Water Quality and Flow Data

In 1999 the OCC installed automated samplers in both Beaty Creek and Little Saline Creeks to monitor pollutant loads using continuous, flow-weighted sampling. Figure 1 shows the sampler locations used in this study. Station EUC 06 (USGS07191222) provided information on the water quality and discharge data from the Beaty Creek watershed, just upstream from the confluence of Beaty and Spavinaw Creeks. Samplers were programmed to pull samples based upon the passage of 10,000 cubic feet of water. This sampling regime provided a higher sampling frequency during periods of runoff than during base flows. These data were used to estimate weekly TP loads. Over time this type of sampling resulted in more accurate estimates of pollution loads than weekly or monthly grab samples (OCC 2005).

The City of Tulsa, in collaboration with the USGS, had an extensive stream monitoring program in the Eucha-Spavinaw Lake basin. The system of monitoring sites allowed quantification of nutrient inputs from subbasins throughout the entire basin. For Station EUC 10 (USGS07191179) on Spavinaw Creek the City of Tulsa collected monthly grab samples, and the USGS collected storm-event water quality data using the equal-width-increment methodology (EWI) and continuous discharge data (Figure 1) (USGS 1998; 2006). Using these data, weekly TP loads were estimated using a statistical multiple regression-loading model (Loadest2 1999; OCC 2005). This station was directly downstream from the only significant point source discharge into Spavinaw Creek, the City of Decatur, AR WWTP. Data from the City of Decatur, AR

WWTP provided the TP load that flowed into Spavinaw Creek. By using data that were collected directly downstream of the City of Decatur point source, the point source load could be subtracted from the total load to estimate the contribution of TP from nonpoint sources.

Statistical Methods

With a paired watershed design it is important to factor out variables other than the treatment effects that have changed over time (specifically weather variation) and may have caused a change in the water quality variable of interest. To accomplish this an ANCOVA was run, where the covariate was the water quality variable of interest, TP, in the control watershed (USEPA 1993).

An ANCOVA is a technique that is between analysis of variance and regression analysis. The ANCOVA's main purpose is to increase the precision of comparisons by accounting for variation between groups. When the imbalance between the groups is not large, this method is very useful. In addition to allowing for imbalances, the method removes variation due to the covariate and therefore provides a more precise analysis (Freund 2003; USEPA 1997b). The equation used in the ANCOVA was expressed as:

$$Y = b_0 + b_1X$$

where the continuous variable X (the covariate) models the relationship with Y. For this study, X was the Log_{10} of the weekly TP load from the control watershed and Y was the Log_{10} of the weekly TP load from the treatment watershed, which yielded the equation:

$$\text{Log}_{10}\ TP_{BC} = b_0\ \text{Period} + b_1\ \text{Log}_{10}\ TP_{LSC}$$

where Period was set to "0" for the calibration period and "1" for the treatment period.

In addition to using the ANCOVA, regression analysis was also preformed to test for a shift in intercepts, slopes, and combined slopes and intercepts that statistically prove that a difference between the two lines was present. These tests used indicator variables to define a group. In this study the calibration period was represented with a "0", and the treatment period with a "1". When testing intercepts to check for parallel lines the equations were:

$$Y = b_0 + b_1X \qquad \text{when indicator} = 0$$

$$Y = b_0 + b_1X + b_2 \qquad \text{when indicator} = 1$$

where the Null Hypothesis is $b_2 = 0$. When testing for differences in slopes with the same intercept the equations became:

$$Y = b_0 + b_1X \qquad \text{when indicator} = 0$$

$$Y = b_0 + b_1X + b_3X \qquad \text{when indicator} = 1$$

where the Null Hypothesis is $b_3 = 0$. Finally, to test for differences in slopes and intercepts together the following equations were used:

$$Y = b_0 + b_1X \qquad \text{where indicator} = 0$$

$$Y = b_0 + b_1X + b_2 + b_3X \qquad \text{where indicator} = 1$$

where the Null Hypothesis is that $b_2 = 0$ and $b_3 = 0$.

Once a difference between the calibration and treatment periods was shown statistically, the next step was to estimate the amount of difference. One method was to find the average difference by using a means approach. By using a “Log_{10} X value” averaged over the entire study period to calculate the average difference in the “Log_{10} Y value”, changes during the treatment period was approximated. Another method was to pair the weekly observations and input the control watershed treatment period data into the calibration and treatment period regression equations and subtract the difference. Once the calibration period minus the treatment period was completed, the weekly values were summed, and the following equation was used to calculate the percent difference (Grabow 1999; OCC 2005):

$$\% \text{ Difference} = ((\text{Calibration-Treatment}) / \text{Calibration}) * 100$$

CHAPTER 4

RESULTS AND DISCUSSION

This research builds upon the work done by the OCC in Beaty Creek. The OCC also used a paired watershed design, but used one year calibration and treatment periods and found a 14 % reduction in TP (OCC 2005). By extending the calibration and treatment periods to two year intervals resulted in a larger data set which was more representative of conditions that occurred in the basin, while still allowing the majority of BMP implementation to occur in the interlude between the calibration and treatment periods.

Beaty Creek Analysis

The first step in this analysis was to plot data from Beaty Creek (BC) and Little Saline Creek (LSC) for the calibration and treatment periods. First, Weekly TP loads were transformed to log base ten values (EPA 1993; EPA 1997a). Based on the USEPA protocol (EPA 1993) the calibration watershed was set on the x-axis while the treatment watershed was set on the y-axis. The $\log_{10}$ transformed calibration and treatment periods data with regression lines are shown in Figures 2 and 3, respectively.

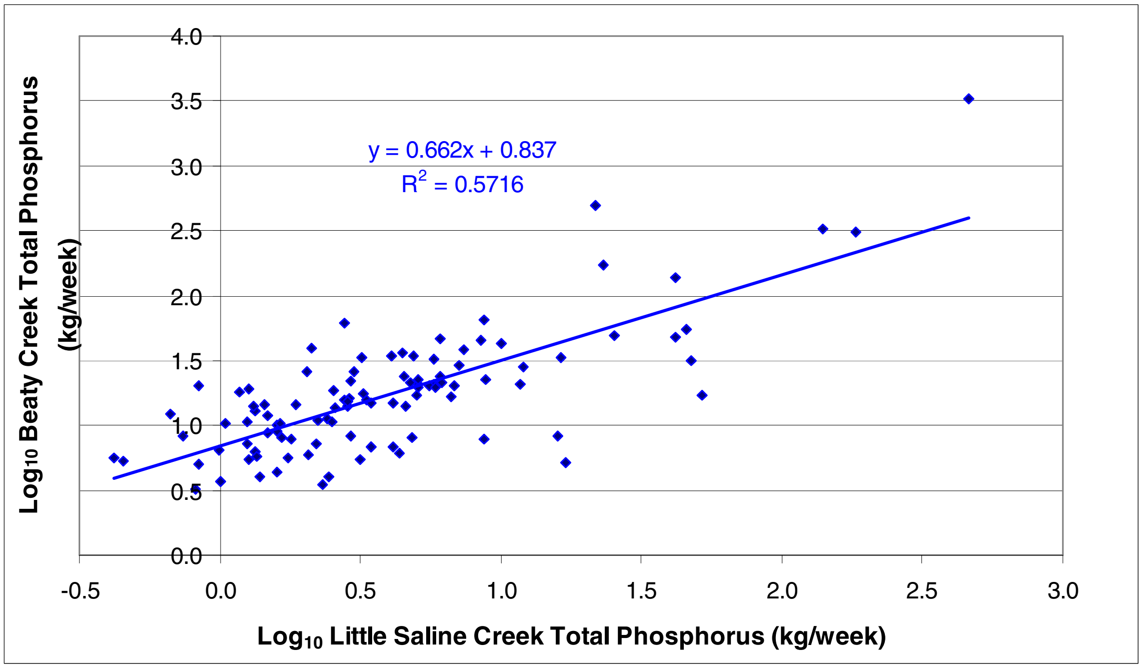

Figure 2. Log $_{10}$ Total Phosphorus Calibration Period (9/1999 – 9/2001) Data and Regression Line for Beaty and Little Saline Creeks.

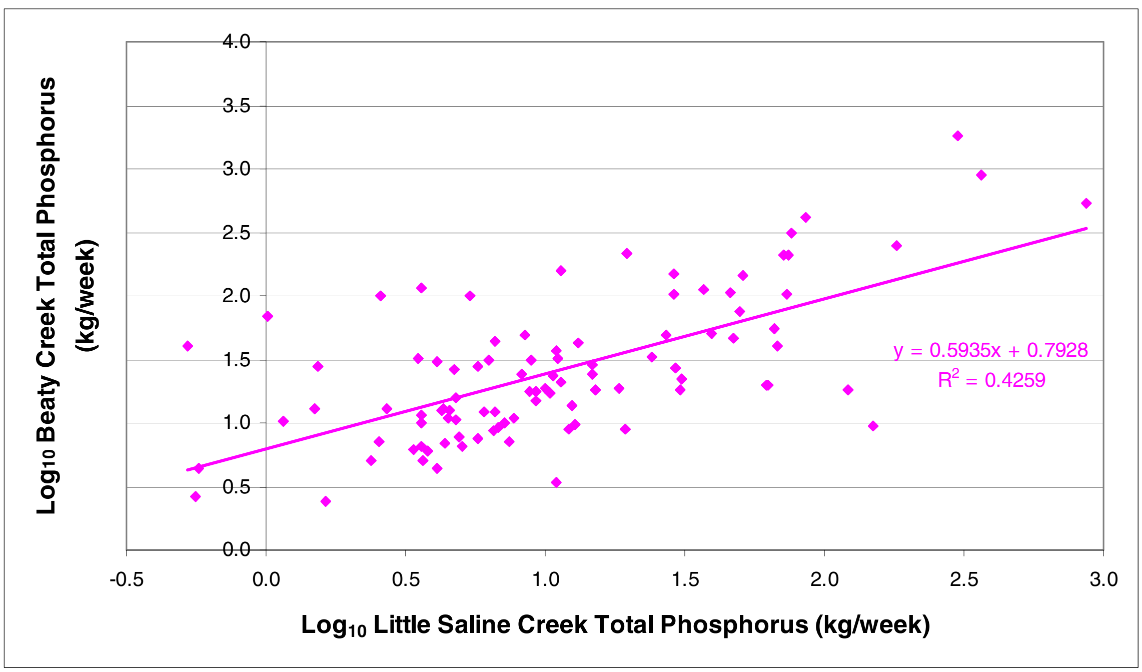

Figure 3. Log_{10} Total Phosphorus Treatment Period (9/2003 – 9/2005) Data and Regression Line for Beaty and Little Saline Creeks.

Using an ANCOVA, the next step in the analysis was to determine if a statistically significant relationship was present in the watersheds between the calibration and treatment periods. The statistical software Minitab V. 14 was used to conduct the analysis (Minitab 2003). An ANCOVA model was used to test the significance of the relationships in BC between the calibration and treatment periods. The periods were distinguished with a "0" representing the calibration period and a "1" representing the treatment period, where Log_{10} BC TP was specified as the *Response Variable*, Period was specified as the *Model*, and Log_{10} LSC TP specified as the *Covariate*. The equation was given as:

$$Log_{10}\ TP_{BC} = b_0\ Period + b_1\ Log_{10}\ TP_{LSC}$$

where b_0 and b_1 were the regression coefficients. The Minitab results of the ANCOVA are shown in Table 3.

Table 3. MINITAB ANCOVA results that test for differences in slope and intercept between the calibration and treatment periods in Beaty Creek.

General Linear Model: Log10 BC TP Load (kg) versus Period Cal=0 Trt=1

Factor	Type	Levels	Values
Period Cal=0 Trt=1	fixed	2	0, 1

Analysis of Variance for Log10 BC TP Load (kg), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Log10 LS T-P Load (kg)	1	27.108	25.890	25.890	185.66	0.000
Period Cal=0 Trt=1	1	0.417	0.417	0.417	2.99	0.085
Error	196	27.332	27.332	0.139		
Total	198	54.857				

S = 0.373426   R-Sq = 50.18%   R-Sq(adj)

Term	Coef	SE Coef	T	P
Constant	0.81088	0.04601	17.63	0.000
Log10 LS TP	0.62351	0.04576	13.63	0.085

The ANCOVA results in Table 3 show P-values of 0.000 for log10 LSC TP coefficient and 0.085 for the Period coefficient. The P-value of 0.000 associated with log10 LSC TP shows that the LSC T-P data were related to the BC TP data significantly for both periods combined. The P-value of 0.085 for the Period indicates that there was a significant difference between the calibration and treatment period regressions at the 0.085 level. Therefore, the first null hypothesis was accepted and thus BMP implementation and reduced litter application reduced P loads to Beaty Creek during the treatment period.

Regression analysis evaluating differences in slopes, intercepts, and combined slopes and intercepts was also completed and are shown in Appendix B (Tables B-4, B-5, and B-6). No difference in the lines (slopes and intercepts) was found when the regression equations were evaluated, but when evaluated independently, the slopes were found to be significantly different at the 0.068 level and the intercepts were significantly different at the 0.085 level. The significant difference in slopes and intercepts supported our ANCOVA finding that an overall shift in the regression line occurred (Figure 4).

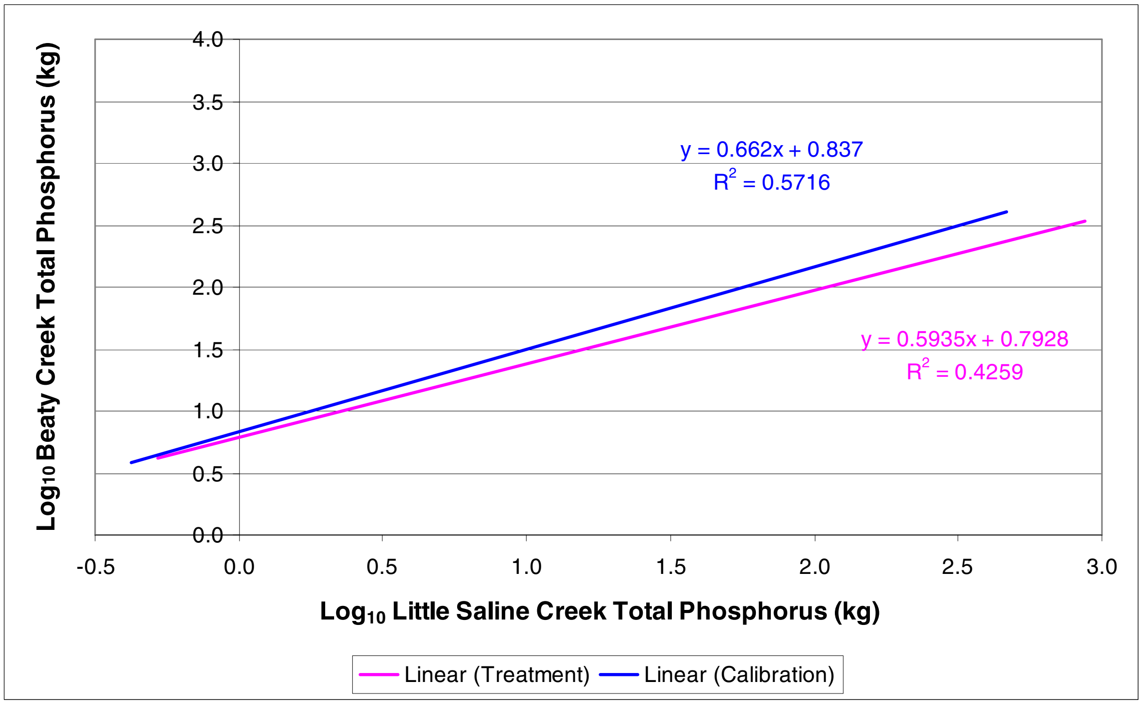

Figure 4. Calibration vs. Treatment Period Regression Equations for Beaty and Little Saline Creeks.

Once it was shown statistically that the calibration and treatment regression lines were different at a 0.085 level, the difference between the two lines was evaluated. To accomplish this task the $\log_{10}$ LSC TP data for the treatment period were input into both the calibration period and treatment period regression equations, as shown in Figure 5. This produced pairs of predicted weekly P loads. These predicted paired data were then transformed back into real space loads (kg/week) and the difference between the paired loads were calculated. An average percent difference was then calculated. Per the EPA protocol (EPA 1993; OCC 2005), the percent reduction in TP during the treatment period was calculated using:

$$\text{TP Reduction (\%)} = ((\text{Predicted} - \text{Observed}) / \text{Predicted}) * 100$$

This resulted in a 31% reduction in TP load to Beaty Creek during the treatment period (Appendix A, Table A-3).

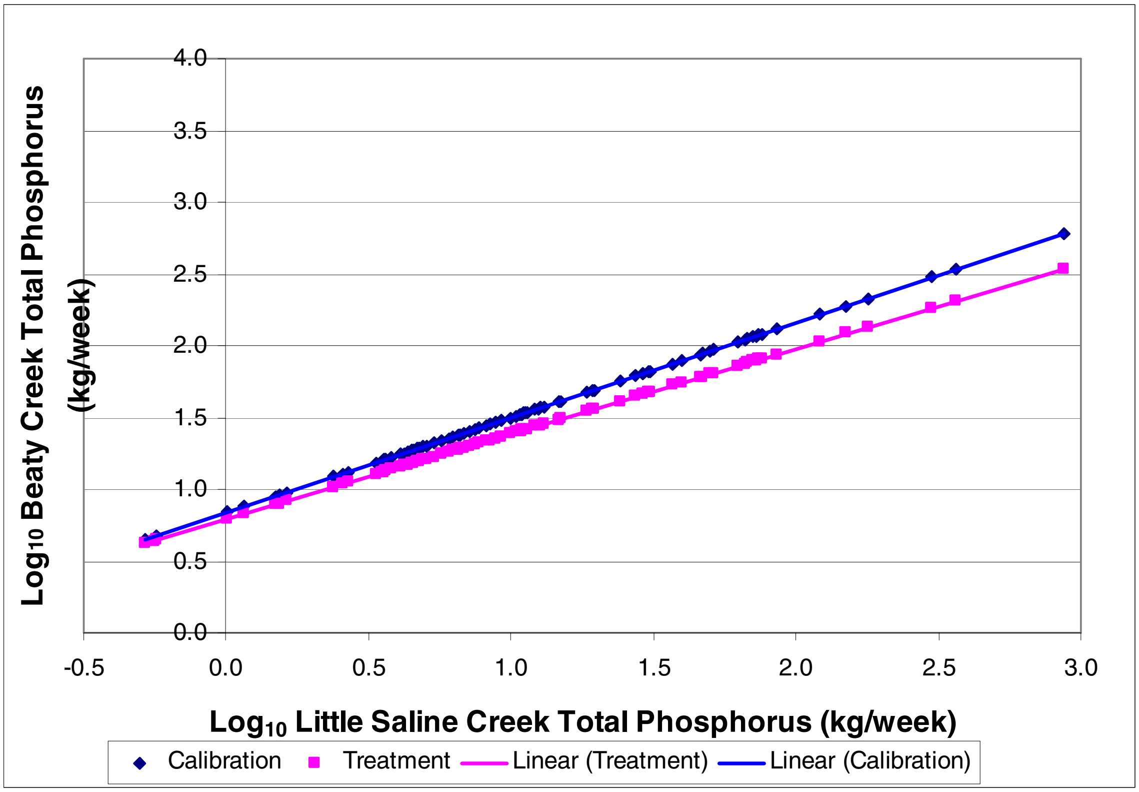

Figure 5. Calibration and Treatment Period Regression Lines with Paired Weekly Loads in Beaty and Little Saline Creeks.

Spavinaw Creek Analysis

Spavinaw Creek had six USGS monitoring stations that collected monthly water quality and daily flow data. Station EUC 10 (USGS07191223) near Colcord, OK was chosen because it was directly downstream of the only significant point source in the basin. However, to use the paired watershed approach weekly concentrations and flow were needed to calculate the TP load to the stream. To acquire these data Loadest2, a USGS program developed to compute loads using the rating-curve method, was used. Using monthly grab sample TP concentrations and daily flow data, Loadest2 estimated a daily TP concentration. By multiplying the estimated daily TP concentration with the daily flow, a daily load was obtained. Daily loads were then summed to correspond to the weekly loads used in the BC and LSC analysis. Figures 6 and 7 compare observed daily TP concentrations with Loadest2 estimated concentrations. These figures show that the estimated TP loads appeared reasonable.

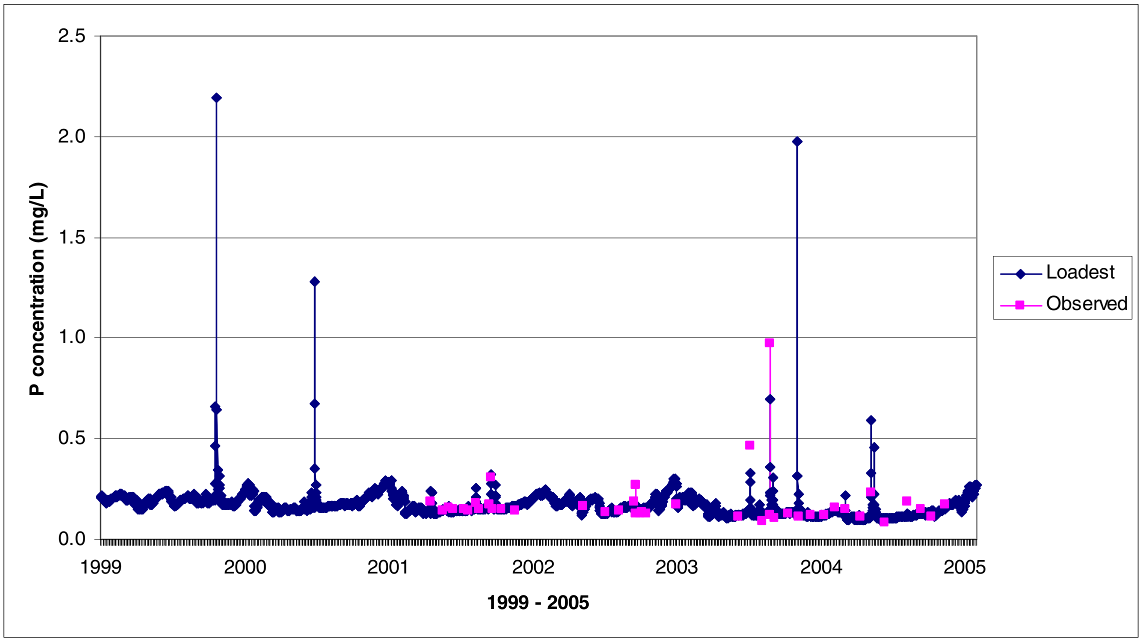

Figure 6. Time Series of Loadest2 Daily Total Phosphorus Concentration Estimates vs. Observed Daily Total Phosphorus Concentrations in Spavinaw Creek.

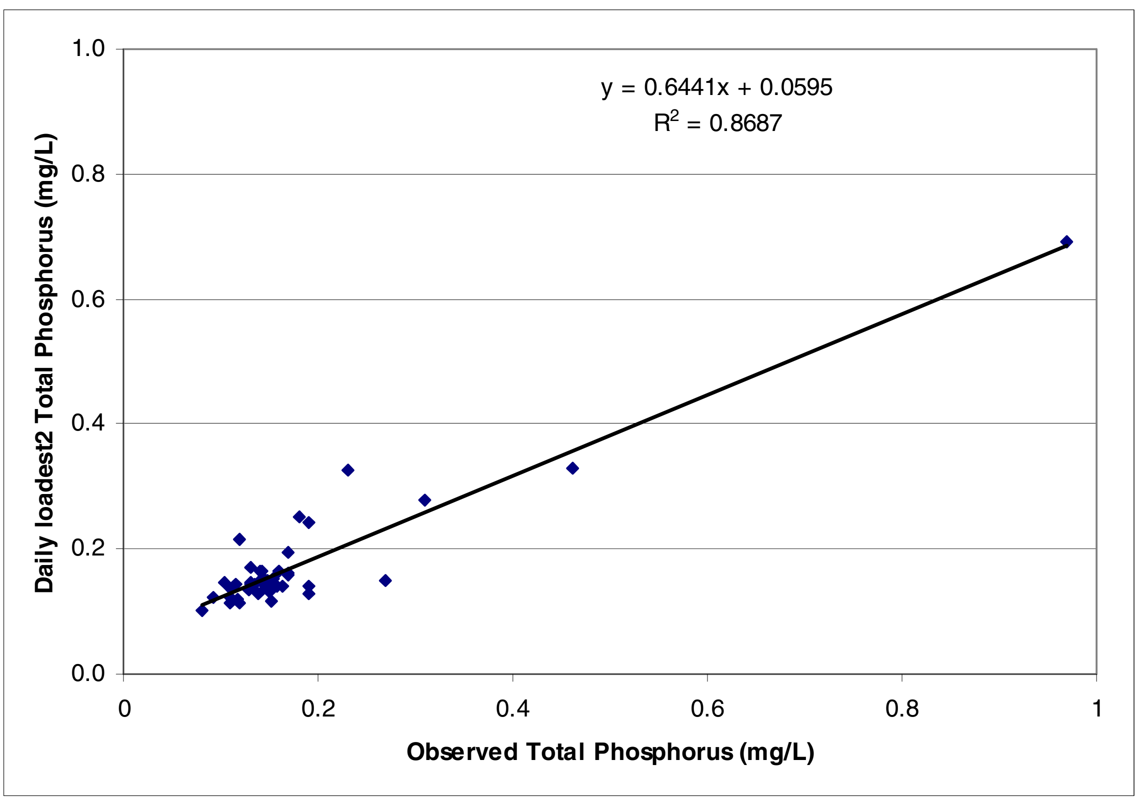

Figure 7. Regression of Loadest2 Daily Total Phosphorus Concentration Estimates vs. Observed Daily Total Phosphorus Concentrations in Spavinaw Creek for the period of 1999-2005.

The problem encountered in this analysis was that the point source must be accurately accounted for if the effects of the reduced litter application on TP runoff were to be evaluated. The City of Tulsa provided water quality data that originated from the Permit Compliance System for the City of Decatur, AR WWTP. When comparing loads from the City of Decatur, AR WWTP and Spavinaw Creek (Figures 8 and 9), it was observed that during portions of the calibration period and treatment periods the loads from the City of Decatur, AR WWTP were higher than what was being estimated in the stream. This was possibly due to inaccurate point source concentrations or stream flow data, and instream assimilation and release processes. It should also be noted that after the calibration period and just prior to the treatment period, there was a substantial reduction in TP load from the WWTP. Thus, it was not possible to accurately account for the point source. Therefore, the second null hypothesis was not accepted, and no conclusions could be drawn as to whether only a reduction in litter application reduced TP loads in Spavinaw Creek.

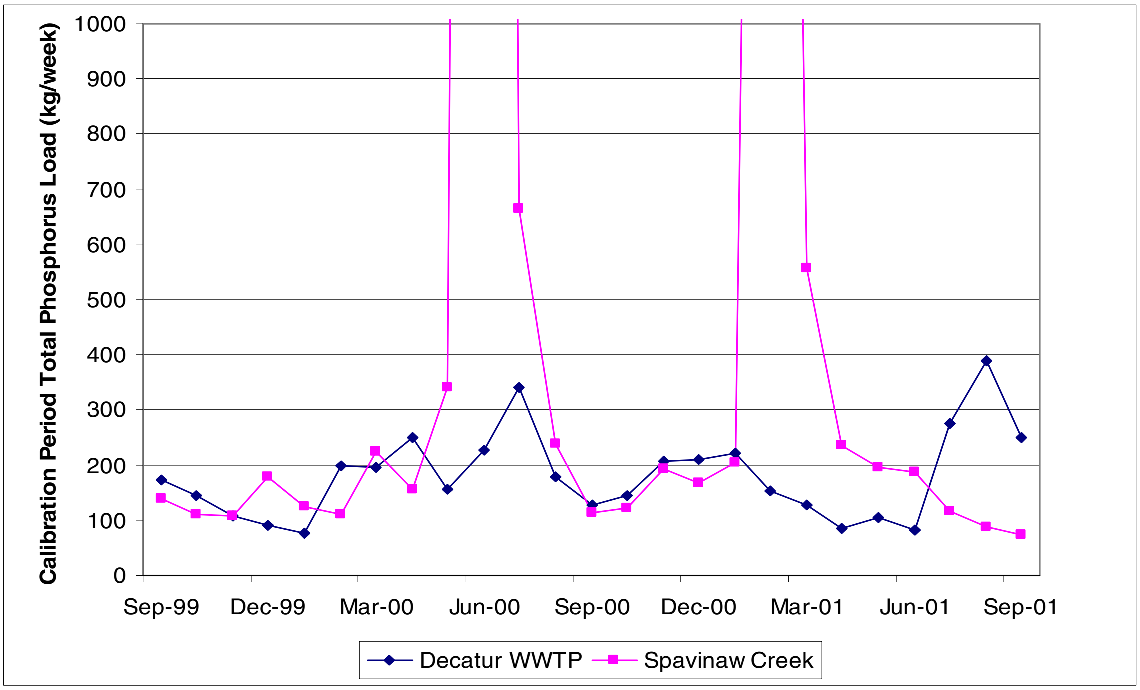

Figure 8. Calibration Period Total Phosphorus Load (kg/week) in City of Decatur, Arkansas Waste Water Treatment Plant Discharge and Spavinaw Creek Station EUC 10.

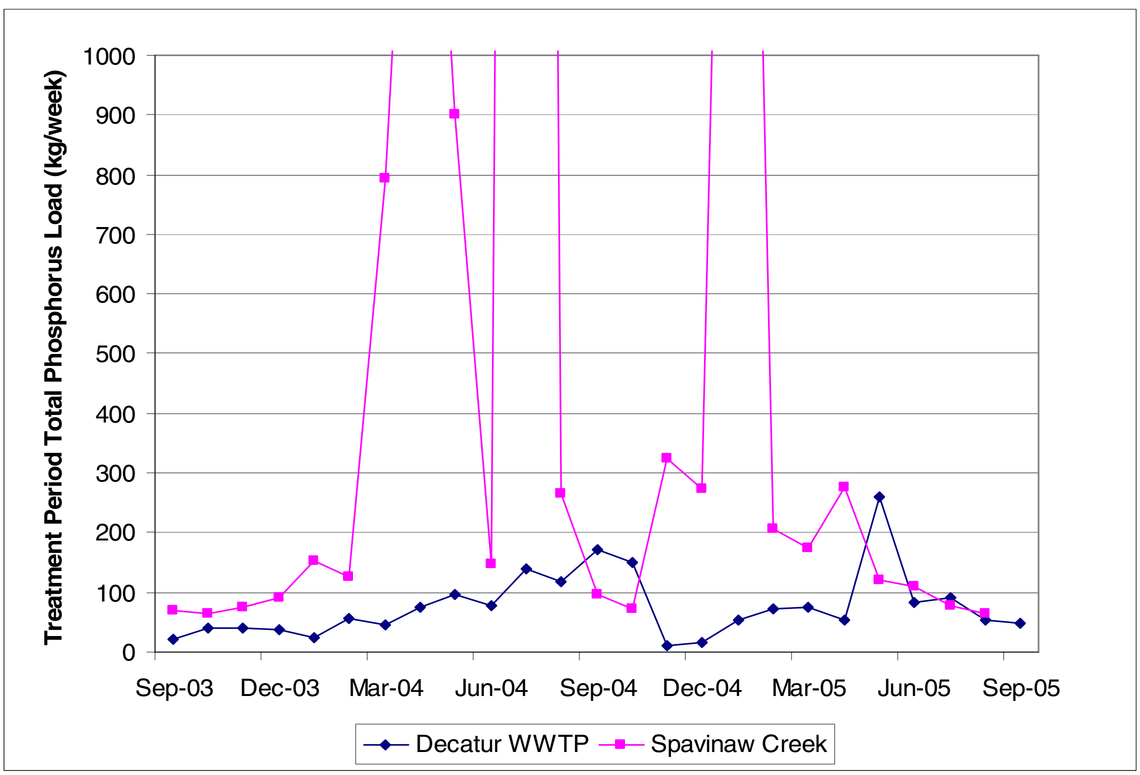

Figure 9. Treatment Period Total Phosphorus Load (kg/week) in City of Decatur, Arkansas Waste Water Treatment Plant Discharge and Spavinaw Creek Station EUC 10.

Even though the point source could not be accounted for and no conclusions could be drawn about the reduced litter application in Spavinaw Creek, the analysis was completed to determine if a reduction in TP had occurred in Spavinaw Creek due to the improvement in the Decatur, AR WWTP, the reduction in litter application, and implementation of NRCS BMPs. Figure 10 illustrates the shift in the regression lines between the calibration and treatment periods in Spavinaw Creek, and Table 4 P-values show that the lines are significantly different. Using the means method, an average of the values of both periods was calculated for Little Saline Creek and input into the calibration and treatment regression equations. A 31% reduction in TP in Spavinaw Creek occurred between the calibration and treatment periods.

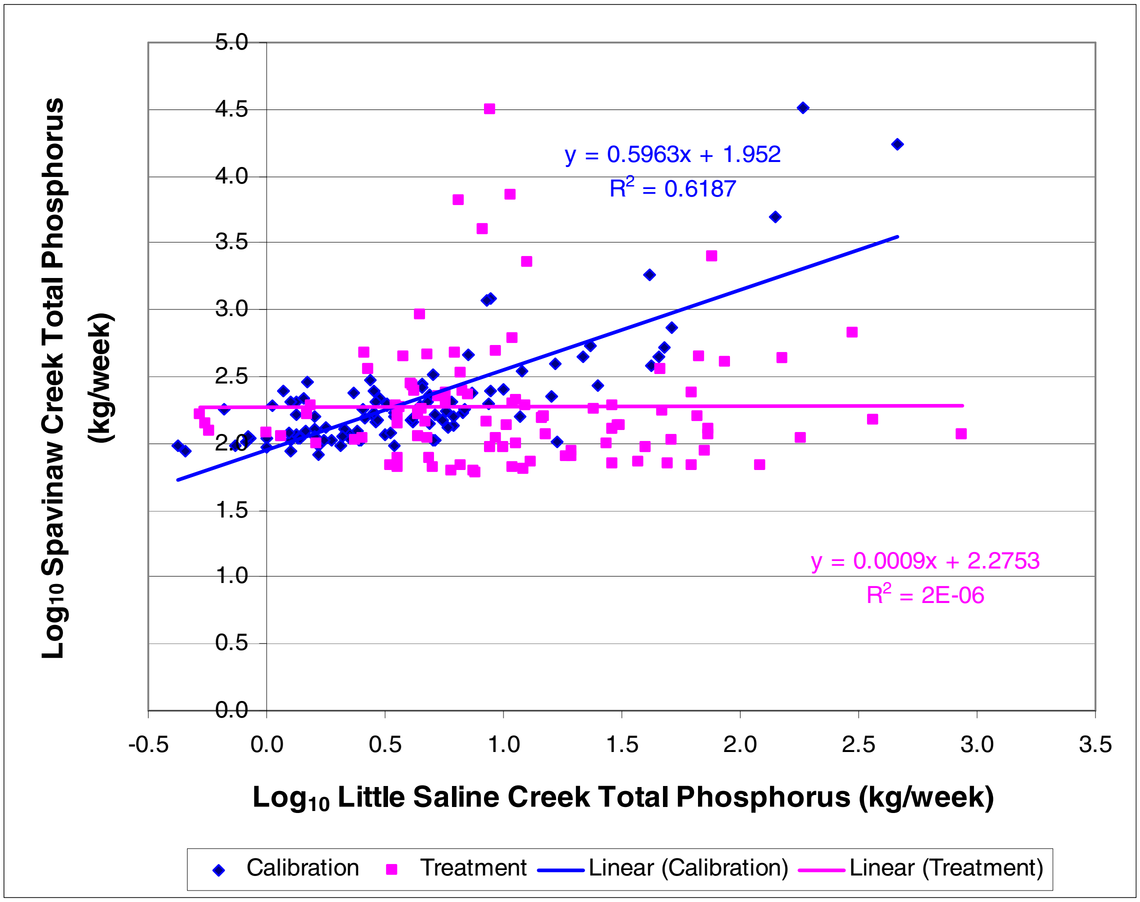

Figure 10. Log_{10} Total Phosphorus Calibration vs. Treatment Period Regression Equations for Spavinaw Creek and Little Saline Creek.

Table 4. MINITAB ANCOVA results that test for differences in slope and intercept between the calibration and treatment periods in Spavinaw Creek.

General Linear Model: Log10 SV TP (kg) versus Period Cal=0 Trt=1

Factor	Type	Levels	Values
Period Cal=0 Trt=1	fixed	2	0, 1

Analysis of Variance for Log10 SV TP (kg), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Log10 LS T-P Load (kg)	1	3.8039	4.7555	4.7555	27.30	0.000
Period Cal=0 Trt=1	1	1.0044	1.0044	1.0044	5.77	0.017
Error	196	34.1434	34.1434	0.1742		
Total	198	38.9517				

S = 0.417374   R-Sq = 12.34%   R-Sq(adj) = 11.45%

Term	Coef	SE Coef	T	P
Constant	2.07267	0.05142	40.31	0.000
Log10 LS TP	0.26722	0.05115	5.22	0.000

Beaty Creek vs. Spavinaw Creek Analysis

The final step in the analysis was one that stretched the limits of the paired watershed approach. As shown, to complete a paired watershed analysis a treatment watershed and a calibration watershed were needed. The calibration period provided baseline data in both watersheds. A change then occurs in the treatment watershed while the land use in the calibration watershed remains unchanged. However, using Spavinaw Creek as the calibration watershed, the court imposed litter application reduction that occurred in both Beaty Creek and Spavinaw Creek may have offset each other. This would allow for teasing out the effects of only the BMPs implemented in Beaty Creek by the OCC, which would give a better indication as to whether the BMPs implemented by the OCC had a significant effect.

Once again, inaccurate point source contributions to stream TP in Spavinaw Creek interfered with the analysis. With this in mind, using Spavinaw Creek as the calibration watershed, the response of Beaty Creek to the implemented OCC BMPs was tested. As Figure 11 shows, the treatment period regression was below the calibration period regression, and as Table 5 P-values show, the treatment period regression line was significantly different than the calibration period regression. However, due to the point source, the third null hypothesis was not accepted and no conclusions were drawn as to whether the BMP implementation reduced stream TP in Beaty Creek without the influence of the reduced litter application. The analysis was completed using the means method and no reduction was calculated in stream TP when comparing the predicted and observed regression equations.

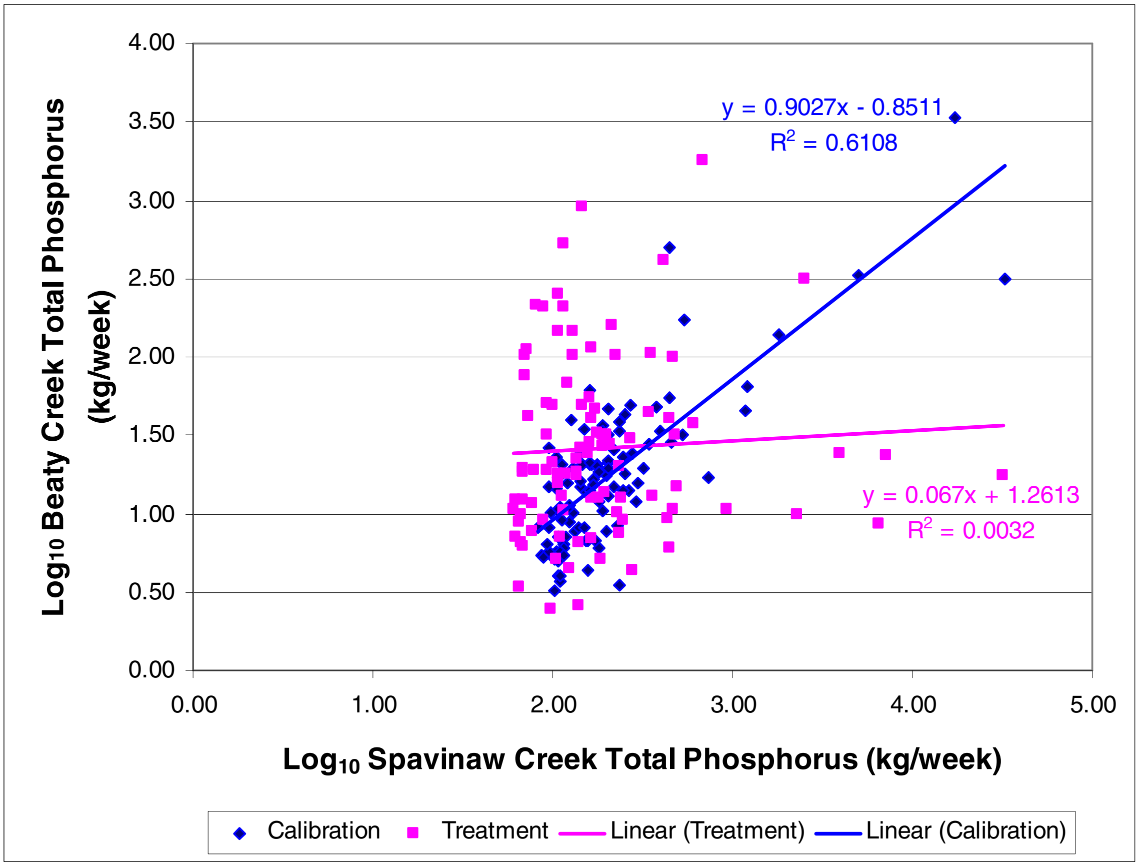

Figure 11. Log_{10} Total Phosphorus Calibration vs. Treatment Period Regression Equations for Beaty Creek with Spavinaw Creek as the Calibration Watershed.

Table 5. MINITAB ANCOVA results that test for differences in slope and intercept between the calibration and treatment periods in Beaty Creek when using Spavinaw Creek as the calibration watershed.

General Linear Model: Log10 BC TP Load (kg) versus Period Cal=0 Trt=1

Factor	Type	Levels	Values
Period	fixed	2	0, 1

Analysis of Variance for Log10 BC TP Load (kg/week), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Log10 SV TP (kg/week)	1	7.0999	7.3630	7.3630	31.47	0.000
Period	1	1.8991	1.8991	1.8991	8.12	0.005
Error	196	45.8581	45.8581	0.2340		
Total	198	54.8571				

S = 0.483705 R-Sq = 16.40% R-Sq(adj) = 15.55%

Term	Coef	SE Coef	T	P
Constant	0.3261	0.1811	1.80	0.073
Log10 SV TP	0.43507	0.07756	5.61	0.000

Storm Flow and Base Flow Analysis

Once this analysis was completed, the relationship between Beaty Creek and Little Saline Creek were evaluated using storm flows and base flows separately. First, weekly flows were ranked as shown in Figure 12. Next, large increases in flow, which indicated storm flows, were identified on the cumulative flow curve. A Cumulative cutoff flow of 13,300,000 cubic feet per week was chosen to distinguish between storm and base flows. Regression analysis was again used in the same way as used previously. It was statistically determined (Figures 13 and 14) that the storm flows did not exhibit a shift in the regression lines which would indicate a reduction stream TP. Therefore, no conclusions were drawn as to the effectiveness of the BMPs on reducing stream TP from storm flows. Base flow regression lines and equations exhibited a similar shift as the overall Beaty Creek analysis. This was primarily due to the majority of weekly flows being classified as base flows in this analysis.

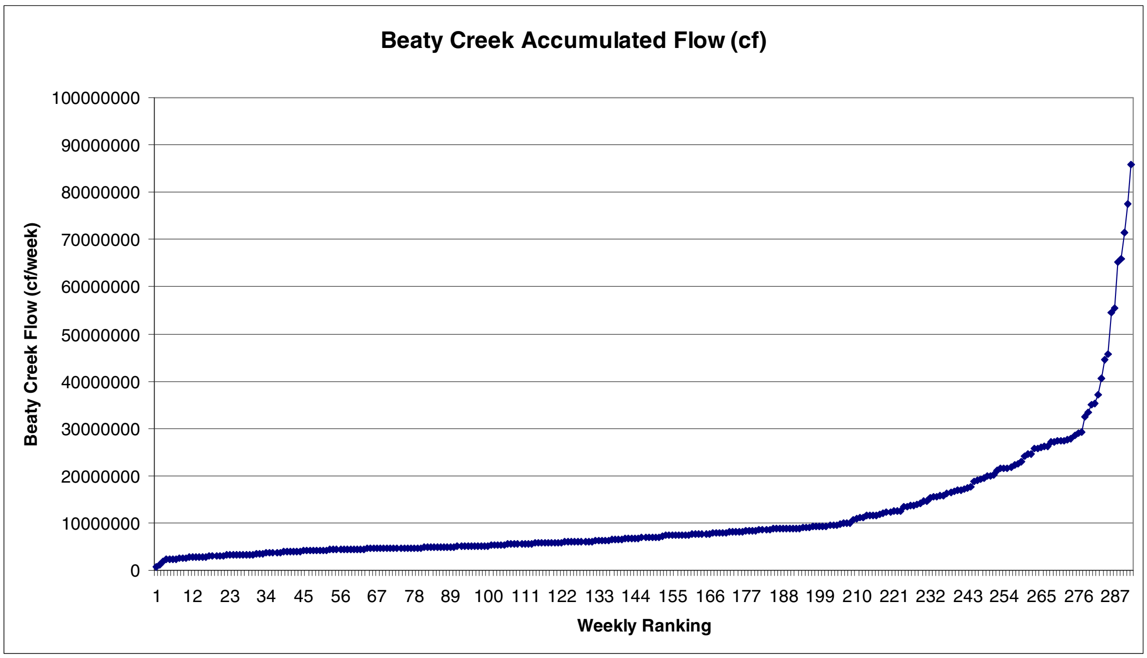

Figure 12. Ranking of Weeks by amount of flow for both calibration and treatment periods for Beaty Creek.

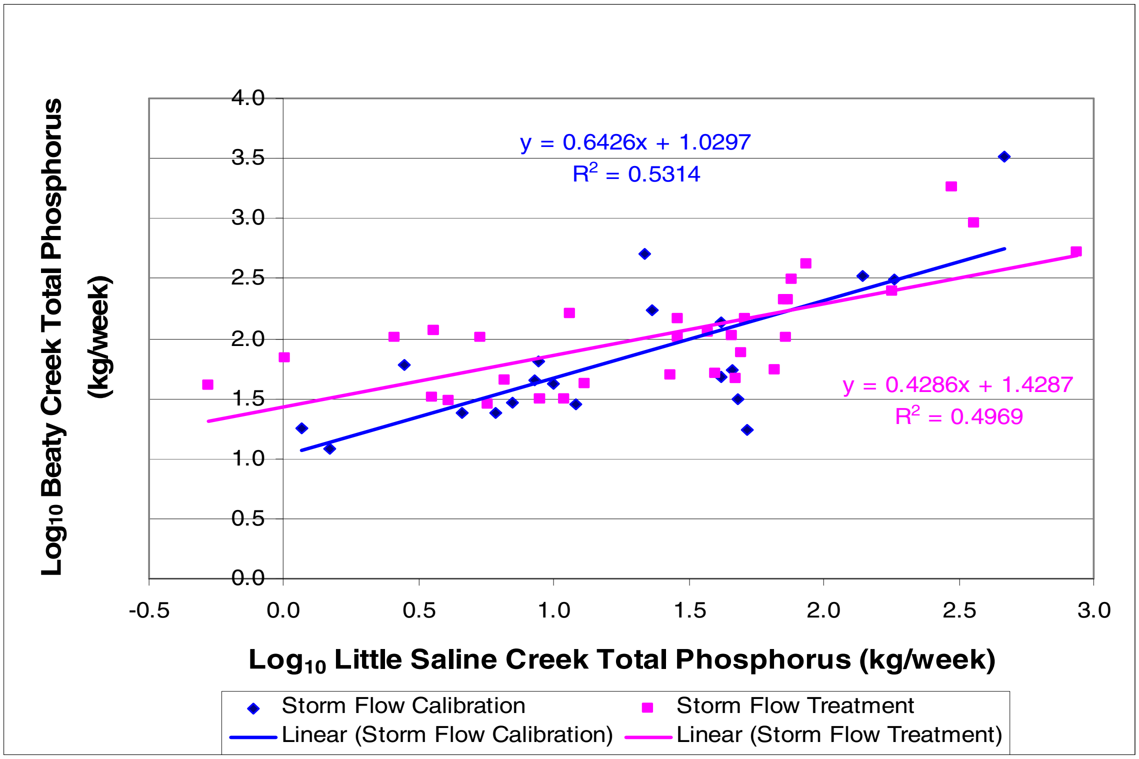

Figure 13. Log_{10} Total Phosphorus Calibration vs. Treatment Period Regression Lines and Equations for Beaty Creek Storm Flows using a base flow cutoff of 13,300,000 cf/week.

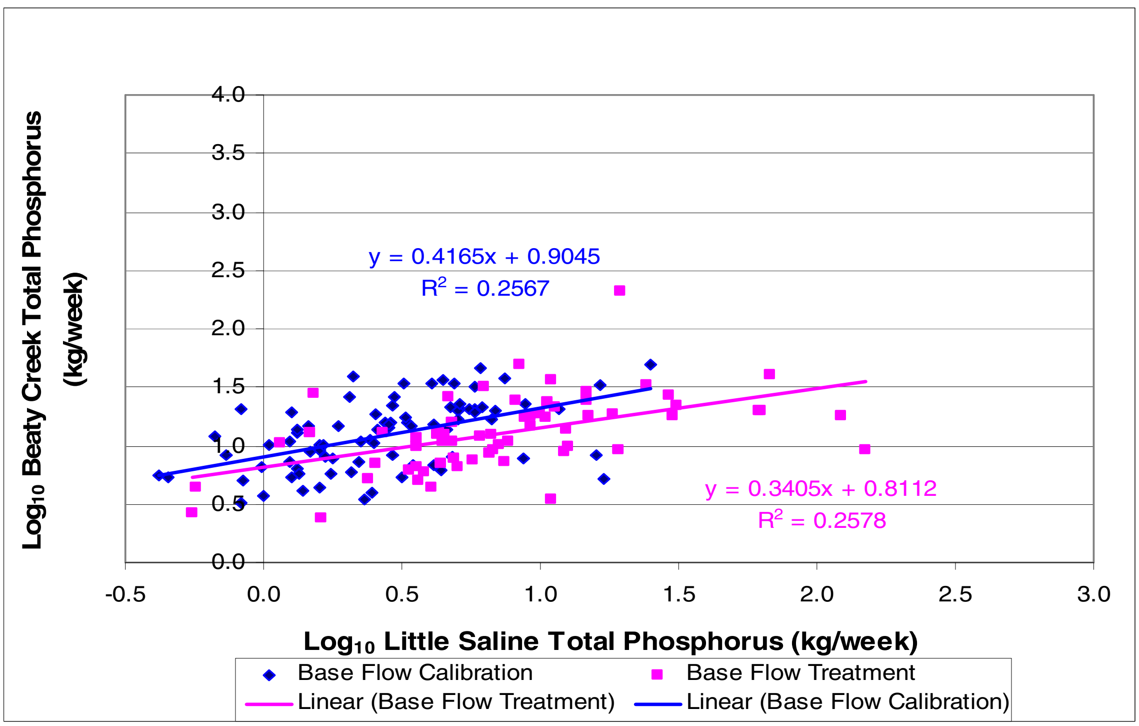

Figure 14. Log_{10} Total Phosphorus Calibration vs. Treatment Period Regression Lines and Equations for Beaty Creek Base Flows using a base flow cutoff of 13,300,000 cf/week.

Unit Effects on the Statistical Analysis

It is important to take note of the units in which the results were reported. Initially the statistical analysis was conducted in units of pounds. However, the analysis was repeated in metric units, i.e. kg. When this conversion was completed, the results proved to be slightly different. The reason for this was that the Log_{10} transformation changed the regression equation coefficients. To illustrate the issue with reporting units, the following equations were used:

$$Log_{10}\ Y_e = a_e + b_e{*}Log_{10}\ X_e$$

$$Log_{10}\ Y_m = a_m + b_m{*}Log_{10}\ X_m$$

where Y and X are the treatment and calibration variables, respectively, and the subscripts e and m represent English (lbs) and Metric (kg) units, respectively. Converting from English units using the transformation of 1.0 lb equal to 0.454 kg, yields:

$$Y_e = 0.454\ Y_m$$

$$X_e = 0.454\ X_m$$

Substituting these equations into the previous English unit equation, yields:

$$Log_{10}\ (0.454\ Y_e) = a_m + b_m{*}Log_{10}\ (0.454\ X_e)$$

Based on the law of logs:

$$Log_{10}\ (0.454\ Y_e) = Log_{10}\ (0.454) + Log_{10}\ (Y_e)$$

Substituting and solving for $Log_{10}\ Y_e$ yields:

$$Log_{10}\ Y_e = b_m{*}Log_{10}\ X_e + [a_m - Log_{10}\ (0.454) + b_m{*}Log_{10}\ (0.454)]$$

where

$$b_e = b_m$$

$$a_e = [a_m - Log_{10}\ (0.454) + b_m{*}Log_{10}\ (0.454)]$$

These equations illustrate that that the slope of the regression line does not change with a unit conversion, i.e. b_m equals b_e. However, the intercept changes with a unit conversion with the amount of change depending on the magnitude of the conversion and the slope. Therefore, a unit conversion changes the ratios between the predicted and observed regression equations and alters the difference between the regression lines.

Due to this influence, special attention must be paid to the units that the results are reported. The problem is magnified as the calibration and treatment watersheds begin to differ in area and loading, which occurred in the Spavinaw Creek vs. Little Saline Creek pairing. Table 6 shows the reductions found in this study in different reporting units and illustrates the need to be aware of this units issue.

Table 6. Differences in Percent Reduction due to Unit Conversions.

Paired Watersheds	Percent Reduction in Real Space	
	lbs	kg
Beaty Creek vs. Little Saline Creek	31%	31%
Spavinaw Creek vs. Little Saline Creek	24%	31%

Discussion

The need to determine the effectiveness of BMPs for reducing stream TP will allow water quality program managers to maximize their pollutant reduction for the money spent on BMPs. However, accurately evaluating the effectiveness of management practices is often very difficult and time consuming.

The findings of this study are consistent with the results of other paired watershed studies that evaluated the association relationship of BMP influences on stream TP. McCoy (2003) found a 98% reduction in stream TP with complete removal of poultry litter from the treatment watershed and nutrient management plans for over 90% of producers in the basin. Their basin contained 54% cropland, and since BMPs that reduce soil erosion have a major impact on stream TP, this may account for the larger reduction that was achieved in that study.

The method for obtaining the percent difference between the Beaty Creek vs. Little Saline Creek pairing and the Spavinaw Creek vs. Little Saline Creek pairing were different. For the Beaty Creek vs. Little Saline Creek analysis each week of the treatment period was evaluated and then the weekly percent differences were averaged to find the overall percent difference. This method calculates a percent difference for each paired weekly TP load, and thus reflects the actual distribution of base flow and high flow events that occurred.

The problem encountered in the Spavinaw Creek vs. Little Saline Creek pairing was that there was no significant correlation between the calibration period regression and the treatment period regression. It can be seen that the correlation no longer existed when looking at the slopes and intercepts of the regression equations in figure 10. When the slope of the treatment period was very small, the loading in Spavinaw Creek had no relationship with the TP loading in Little Saline Creek. When the correlation between the periods ceased to exist, the averaging of weekly TP loads was no longer a valid method. To evaluate the percent difference in this pairing, a Log_{10} mean of the combined calibration and treatment periods was obtained for Little Saline Creek (control watershed). This mean was then input into both the calibration and treatment period regression equations, and the percent difference calculated. It should be noted that the Log_{10} mean approximates the median of the data in real space.

Different methods for evaluating the percent difference between calibration and treatment periods are needed due to three types of relationships that may exist between the regression equations. First, if the regression equations have statistically similar slopes and different intercepts, the intercepts may be used to calculate the percent difference in TP load. If the regression equations have statistically different slopes, the percent difference can be calculated by evaluating the average of the weekly percent differences in TP load, or by using the Log_{10} mean of the calibration watershed data. Finally, if the correlation between the watersheds is statistically insignificant in either of the two periods, the Log_{10} means approach must be used to evaluate the percent difference.

The paired watershed approach proved to be a valuable technique in this study as it was able to document reductions in stream TP in a relatively short time period. The paired watershed approach can and should be used to evaluate BMPs and other land management changes whenever the conditions needed for its use are present. However, decision makers must be further educated on the principles and techniques of the paired watershed approach so they are able to understand the results and properly incorporate them into their decision making process. It should be noted that both watersheds experienced an increase in TP load during the treatment period due to weather influences. Although the actual TP load increased, the paired watershed approach was able to document a reduction in TP load relative to the calibration period. In other words, if BMPs were not implemented during the treatment period, there would have been an even greater increase in TP load from the treatment watershed.

The difficulties in documenting BMP effectiveness are complex. Issues include allowing time for the system to flush sediment and nutrients that were disturbed by the implementation of the BMPs as well as P stored in the stream system prior to BMP implementation. Another issue is the influence of point sources or other pollutant sources that BMPs do not affect. Sampling regimes that gather accurate data are essential. Using appropriate time periods that allow for implemented BMPs to take effect, while also allowing agencies or other individuals to obtain the funding and collect and analyze these data needed to complete the research are critical.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Summary and Conclusions

Using a paired watershed design, a reduction in stream TP from the calibration to treatment periods was found to be 31% in Beaty Creek, and 31% in Spavinaw Creek. These reductions were likely due to the association relationship between water quality and the implementation of NRCS and OCC BMPs, the reduction of poultry litter application to pastures mandated by court order, and in Spavinaw Creek the improvements to the Decatur, AR WWTP. These results suggest that nutrient management plans and best management practices may reduce the amount of TP flowing into and causing eutrophication in Lake Eucha, one of the City of Tulsa's primary drinking water supplies.

It is important for poultry producers in the basin to remember that soils that become saturated with P can directly lead to water quality problems. Reducing soil P accumulation and runoff will decrease the potential for transport of P to receiving water bodies. Producers should focus on managing both the source of P, primarily poultry litter application, and the potential transport of P out of the field.

If followed, nutrient management plans can be an effective tool to ensure that nutrients are not applied at excessive rates. Development and implementation of nutrient management plans should be prepared for all users of poultry litter as fertilizer. The buildup of soil P levels should be monitored using soil test procedures, which are available from local cooperative extension offices, and producers should keep accurate records of their soil test reports over time. This would help prevent applying more P than the vegetation can uptake. Producers should set a goal of not allowing their fields to exceed recommended levels, as excess levels of P can easily be transported off site and into receiving water bodies. Producers also should remember that it may take years, decades, or even centuries to reduce soil test P from very high levels after stopping P additions. Transportation of poultry litter to other areas that can utilize this P must be part of the nutrient management plans if soil test results do not recommend the application of additional poultry litter.

Implementation of BMPs is a site specific approach that attempts to reduce the amount of a pollutant from reaching a receiving water body. Effectiveness of the implemented BMPs is a result of the climate, topography, site selection, installation, and maintenance of the BMPs. If these factors are not taken into account, the BMPs may not function to their maximum potential, and the greatest reduction in the pollutant loads will not be achieved. Most BMPs are not used alone, but in conjunction with each other. It is important to take into account how BMPs interact with and affect all other BMPs, and a combination of BMPs may be selected to achieve the greatest reduction of pollutant loads.

Recommendation for Future Research

It is my recommendation that further research should take place in the Spavinaw and Beaty Creeks basin examining different management strategies for dealing with P. One issue that must be addressed is the effectiveness of the nutrient management plans. While the plans are often written within specifications of the amount of nutrients the soil needs, producers must strictly abide by the plans if they are to reduce the amount of P entering water bodies. Research should be conducted to determine how well the producers adhere to their nutrient management plan, and how water quality is impacted by their willingness or refusal to participate.

Research should continue on the effects of best management practices in the basin and throughout the region. Research should focus on identifying individual BMPs and combinations of BMPs that gain the greatest reduction in P entering water bodies. This would allow water quality program managers to gain the maximum effect for the least amount of money spent. The effect of time on BMPs should be studied, as knowing how long a certain BMP can be expected to function would provide guild lines for proper maintenance and upkeep.

The paired watershed study approach should continue to be developed and used. This approach is considered the most appropriate for documenting water quality changes over short time periods. Many agencies and organizations would benefit by using this approach, even if it is only used for preliminary findings, as it can quickly provide results that justify money spent on land management changes.

Finally, it is my opinion that the majority of research should be focused on developing tools for targeting of BMPs. Targeting of BMPs is the process of determining what areas or sources have the worst impact on water quality and treating those areas with the appropriate BMPs first. The saying "10% of the area gives us 90% of the problem" is often correct. Targeting saves time and money by gaining a large reduction of a pollutant while treating fewer sources or areas.

To accurately and efficiently proceed with targeting, geographic information systems (GIS) must be used. A GIS allows land use data, hydrologic data, topographic data, soil data, ect., to be incorporated together to locate and define problem areas that contribute the most pollution to water bodies. Tools can also be used in conjunction with a GIS to estimate the effectiveness of certain BMPs in each problem area. This allows for water quality program managers to identify problem areas and sources and how best to treat them. While these types of programs are available, research on and development of these programs is needed to make them more user friendly and widely applicable.

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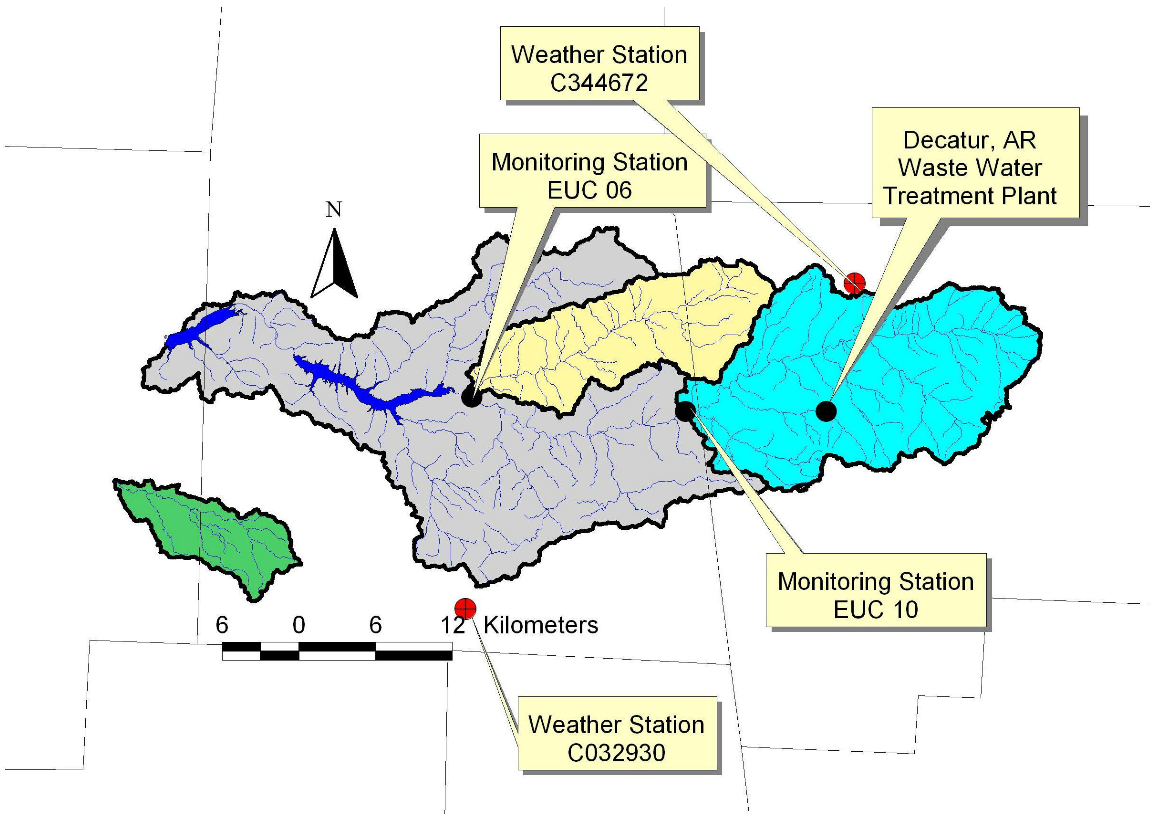
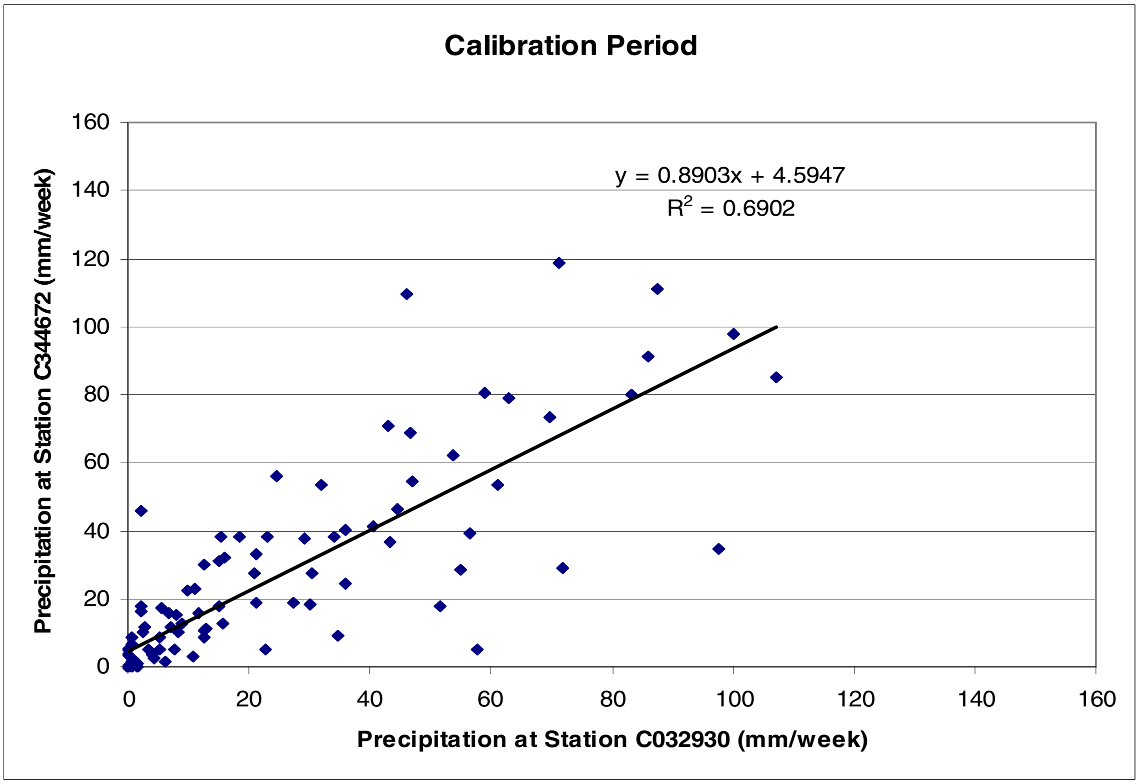
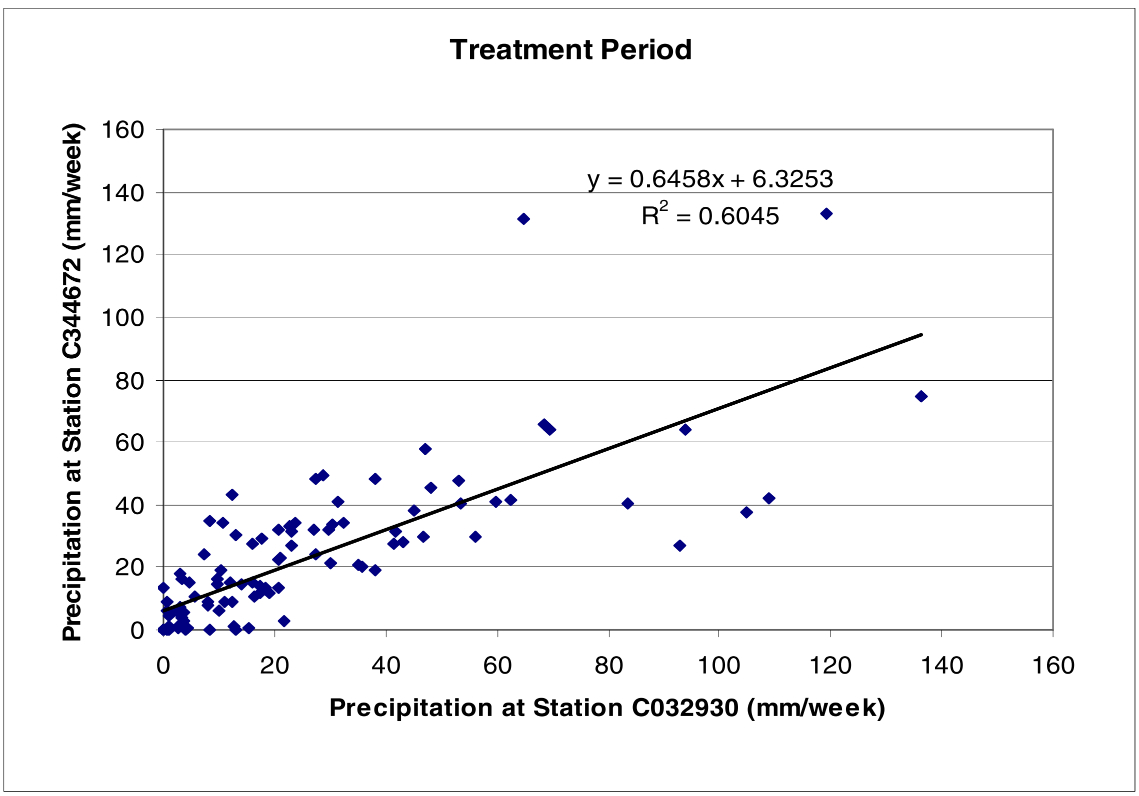
APPENDIX A

Precipitation Data
National Oceanic and Atmospheric Administration's (NOAA)
National Weather Service Cooperative Observer Program (COOP)




Calibration Period
y = 0.8903x + 4.5947
R2 = 0.6902
Precipitation at Station C344672 (mm/week)
Precipitation at Station C032930 (mm/week)
0
20
40
60
80
100
120
140
160


Treatment Period
y = 0.6458x + 6.3253
R2 = 0.6045
Precipitation at Station C344672 (mm/week)
Precipitation at Station C032930 (mm/week)
0
20
40
60
80
100
120
140
160

APPENDIX B

Beaty Creek

Table B-1. Beaty Creek and Little Saline Creek Raw Data used in this Study (Courtesy of Oklahoma Conservation Commission).

BC and LS DateActivityStart	BC Total Phosphorus (mg/l)	LS Total Phosphorus (mg/l)	BC Accumulated flow (cf)	LS Accumulated flow (cf)	BC TP Load (lbs)	LS TP Load (lbs)	Log10 BC TP Load (lbs)	Log10 LS TP Load (lbs)	Period
09/07/99	0.078	0.026	4551568	2171232	22.12	3.52	1.34	0.55	Cal
09/14/99	0.062	0.023	8567561	6326208	33.10	9.07	1.52	0.96	Cal
09/22/99	0.070	0.021	6859185	4347648	29.91	5.69	1.48	0.75	Cal
09/28/99	0.063	0.030	4379438	2104704	17.19	3.93	1.24	0.59	Cal
10/05/99	0.052	0.028	4863923	2776032	15.76	4.84	1.20	0.69	Cal
10/12/99	0.083	0.026	4663123	3096576	24.11	4.92	1.38	0.69	Cal
10/19/99	0.114	0.023	4529256	2866752	32.17	4.11	1.51	0.61	Cal
10/26/99	0.040	0.210	4596190	2848608	11.45	37.27	1.06	1.57	Cal
11/02/99	0.039	0.018	5131655	3435264	12.47	3.85	1.10	0.59	Cal
11/09/99	0.042	0.013	5354766	3622752	14.01	2.93	1.15	0.47	Cal
11/16/99	0.036	0.009	4886234	3314304	10.96	1.86	1.04	0.27	Cal
11/22/99	0.035	0.028	4073458	3094848	8.88	5.40	0.95	0.73	Cal
11/30/99	0.040	0.010	7853622	5204736	19.57	3.24	1.29	0.51	Cal
12/07/99	0.111	0.010	19366119	9876384	133.93	6.15	2.13	0.79	Cal
12/14/99	0.067	0.013	22467358	27252288	93.79	22.07	1.97	1.34	Cal
12/21/99	0.067	0.016	10820979	12773376	45.17	12.73	1.65	1.10	Cal
12/29/99	0.172	0.013	8108605	5778432	86.89	4.68	1.94	0.67	Cal
01/04/00	0.056	0.015	5756350	3748032	20.08	3.50	1.30	0.54	Cal
01/11/00	0.080	0.021	7050408	4838400	35.14	6.33	1.55	0.80	Cal
01/18/00	0.063	0.021	6358764	4076352	24.96	5.33	1.40	0.73	Cal
01/25/00	0.035	0.016	6046409	4584384	13.19	4.57	1.12	0.66	Cal
02/01/00	0.035	0.014	5845610	3417120	12.75	2.98	1.11	0.47	Cal
02/07/00	0.026	0.011	4991399	3234816	8.09	2.22	0.91	0.35	Cal
02/14/00	0.025	0.012	5756365	4082400	8.97	3.05	0.95	0.48	Cal
02/23/00	0.024	0.013	7946069	8553600	11.88	6.93	1.07	0.84	Cal
03/01/00	0.052	0.007	16264880	30838752	52.70	13.45	1.72	1.13	Cal
03/06/00	0.031	**0.002**	13673578	24727680	26.41	3.27	1.42	0.51	Cal
03/13/00	0.044	**0.002**	14569239	19462464	39.94	2.57	1.60	0.41	Cal

03/20/00	0.129	0.014	9906225	11273472	79.62	9.83	1.90	0.99	Cal
03/27/00	0.067	0.016	8835293	14757120	36.88	14.71	1.57	1.17	Cal
04/03/00	0.080	0.020	9103026	20829312	45.37	25.95	1.66	1.41	Cal
04/10/00	0.166	0.018	7273518	8001504	75.23	8.97	1.88	0.95	Cal
04/17/00	0.080	0.018	9214582	10033632	45.93	11.25	1.66	1.05	Cal
04/24/00	0.032	0.020	7496629	7281792	14.95	9.07	1.17	0.96	Cal
05/01/00	0.025	0.020	8567561	7735392	13.34	9.64	1.13	0.98	Cal
05/08/00	0.052	0.041	21507982	41132448	69.68	105.07	1.84	2.02	Cal
05/15/00	0.072	0.042	27152683	38453184	121.80	100.62	2.09	2.00	Cal
05/22/00	0.113	0.020	10017780	10215072	70.53	12.73	1.85	1.10	Cal
05/30/00	0.037	0.062	16370077	29569536	37.74	114.22	1.58	2.06	Cal
06/05/00	0.207	0.072	8338060	12369024	107.54	55.49	2.03	1.74	Cal
06/12/00	0.108	0.042	6626497	5757696	44.59	15.07	1.65	1.18	Cal
06/19/00	0.400	0.100	29138369	49557312	726.17	308.76	2.86	2.49	Cal
06/27/00	0.242	0.075	45744197	86600448	689.71	404.67	2.84	2.61	Cal
07/05/00	0.146	0.035	33504980	42142464	304.77	91.90	2.48	1.96	Cal
07/10/00	0.124	0.038	9498220	15303600	73.38	36.23	1.87	1.56	Cal
07/17/00	0.135	0.029	8857604	5975424	74.50	10.80	1.87	1.03	Cal
07/24/00	0.094	0.021	8009784	8019648	46.91	10.49	1.67	1.02	Cal
07/31/00	0.718	0.073	24609221	10475136	1100.88	47.64	3.04	1.68	Cal
08/07/00	0.116	0.051	11691111	5122656	84.49	16.28	1.93	1.21	Cal
08/14/00	0.120	0.058	6001787	3386880	44.87	12.24	1.65	1.09	Cal
08/21/00	0.109	0.041	5042411	2866752	34.24	7.32	1.53	0.86	Cal
08/28/00	0.083	0.040	4551568	2201472	23.54	5.49	1.37	0.74	Cal
09/06/00	0.176	0.027	5220931	2671056	57.25	4.49	1.76	0.65	Cal
09/11/00	0.068	0.032	2804898	1395360	11.88	2.78	1.07	0.44	Cal
09/18/00	0.079	0.028	4596190	2077488	22.62	3.62	1.35	0.56	Cal
09/25/00	0.087	0.011	4908545	2139480	26.61	1.47	1.42	0.17	Cal
10/04/00	0.187	0.040	6368357	2830464	74.20	7.05	1.87	0.85	Cal
10/09/00	0.082	0.030	3091755	1477440	15.80	2.76	1.20	0.44	Cal
10/16/00	0.045	0.006	4440012	2485728	12.45	0.93	1.10	-0.03	Cal
10/23/00	0.050	0.013	4573879	2700432	14.25	2.19	1.15	0.34	Cal
10/30/00	0.022	0.010	5176278	2915136	7.10	1.82	0.85	0.26	Cal
11/06/00	0.132	0.007	5466322	4221504	44.96	1.84	1.65	0.27	Cal
11/13/00	0.070	0.019	7987473	5140800	34.84	6.09	1.54	0.78	Cal
11/20/00	0.122	0.046	6202587	4717440	47.15	13.52	1.67	1.13	Cal
11/27/00	0.239	0.046	6894230	4650912	102.66	13.33	2.01	1.12	Cal
12/04/00	0.035	0.067	7853606	4578336	17.13	19.11	1.23	1.28	Cal
12/11/00	0.049	0.033	5890232	5189184	17.98	10.67	1.25	1.03	Cal
12/18/00	0.040	0.024	5979476	5189184	14.90	7.60	1.17	0.88	Cal
12/25/00	0.036	0.024	6715742	5189184	14.85	7.60	1.17	0.88	Cal
01/04/01	0.031	0.014	9370806	7413120	18.10	6.47	1.26	0.81	Cal
01/08/01	0.033	0.017	4691762	3317760	9.65	3.51	0.98	0.55	Cal
01/16/01	0.054	0.016	15834611	10056960	53.27	10.03	1.73	1.00	Cal
01/22/01	0.033	0.028	8892649	20145888	18.28	35.14	1.26	1.55	Cal
01/29/01	0.086	0.067	19879274	22130496	105.90	92.38	2.02	1.97	Cal
02/05/01	0.138	0.026	44488386	31491936	382.51	51.01	2.58	1.71	Cal

02/12/01	0.060	0.037	16599546	11454912	62.05	26.41	1.79	1.42	Cal
02/20/01	0.062	0.012	37202243	25850880	143.71	19.33	2.16	1.29	Cal
02/28/01	1.1	0.276	65122894	59602176	7322.86	1024.91	3.86	3.01	Cal
03/05/01	0.093	0.017	17131794	17651520	99.27	18.70	2.00	1.27	Cal
03/12/01	0.067	0.025	15238571	9997344	63.61	15.57	1.80	1.19	Cal
03/19/01	0.060	0.024	11646488	7457184	43.54	11.15	1.64	1.05	Cal
03/26/01	0.051	0.025	9660803	6462288	30.70	10.07	1.49	1.00	Cal
04/02/01	0.015	0.015	8277517	5467392	7.74	5.11	0.89	0.71	Cal
04/09/01	0.121	0.023	7518940	4590432	56.68	6.58	1.75	0.82	Cal
04/16/01	0.105	0.031	7675118	10088064	50.21	19.48	1.70	1.29	Cal
04/23/01	0.062	0.015	8009784	6707232	30.94	6.27	1.49	0.80	Cal
05/01/01	0.081	0.026	7573140	4409856	38.22	7.14	1.58	0.85	Cal
05/07/01	0.132	0.031	5010523	2913408	41.21	5.63	1.61	0.75	Cal
05/14/01	0.137	0.038	5667121	2715552	48.37	6.43	1.68	0.81	Cal
05/22/01	0.065	0.014	7063172	3366144	28.60	2.94	1.46	0.47	Cal
05/29/01	0.064	0.012	5711743	3084480	22.78	2.31	1.36	0.36	Cal
06/04/01	0.125	0.015	5469493	3084480	42.60	2.79	1.63	0.45	Cal
06/11/01	0.094	0.017	5220900	2757888	30.58	2.92	1.49	0.47	Cal
06/18/01	0.081	0.015	6403387	3405024	32.32	3.18	1.51	0.50	Cal
06/25/01	0.094	0.028	5689432	3592512	33.32	6.27	1.52	0.80	Cal
07/02/01	0.145	0.087	4774678	2376864	43.13	12.88	1.63	1.11	Cal
07/09/01	0.085	0.027	4484634	1632960	23.75	2.75	1.38	0.44	Cal
07/16/01	0.199	0.116	4038413	1554336	50.07	11.23	1.70	1.05	Cal
07/23/01	0.158	0.165	3815302	1076544	37.56	11.07	1.57	1.04	Cal
07/30/01	0.147	0.147	3569880	828576	32.70	7.59	1.51	0.88	Cal
08/06/01	0.084	0.034	3480636	768096	18.22	1.63	1.26	0.21	Cal
09/08/03	0.11	0.075	6024098	8704282	41.29	40.67	1.62	1.61	Trt
09/15/03	0.112	0.052	2448632	3343334	17.09	10.83	1.23	1.03	Trt
10/13/03	0.1	0.060	3971480	2126536	25.49	7.95	1.41	0.90	Trt
11/10/03	0.05	0.052	4328457	2286144	13.75	7.41	1.14	0.87	Trt
11/17/03	0.08	0.054	4172279	2346624	21.84	7.90	1.34	0.90	Trt
11/24/03	0.04	0.049	3469054	7868448	7.56	24.02	0.88	1.38	Trt
12/01/03	0.08	0.055	4796989	4947264	23.91	16.95	1.38	1.23	Trt
12/08/03	0.086	0.053	2671200	3380832	14.31	11.16	1.16	1.05	Trt
12/15/03	0.08	0.056	5756365	4203965	27.26	14.67	1.44	1.17	Trt
12/22/03	0.07	0.048	5979476	4457376	26.82	13.33	1.43	1.12	Trt
12/29/03	0.089	0.062	2858437	4257792	15.85	16.45	1.20	1.22	Trt
01/05/04	0.083	0.055	3780000	7827920	19.55	26.82	1.29	1.43	Trt
01/12/04	0.09	0.610	7407385	7081420	40.15	269.13	1.60	2.43	Trt
01/20/04	0.234	0.057	21852226	31760640	318.59	112.79	2.50	2.05	Trt
01/26/04	0.096	0.085	18733782	16500672	112.05	87.38	2.05	1.94	Trt
02/02/04	0.080	0.052	8723738	42287420	43.48	137.00	1.64	2.14	Trt
02/09/04	0.072	0.047	15531896	6663921	69.67	19.51	1.84	1.29	Trt
02/17/04	0.078	0.054	8093172	6048000	39.33	20.35	1.59	1.31	Trt
02/24/04	0.089	0.062	7474318	5691343	41.45	21.98	1.62	1.34	Trt
03/01/04	0.100	0.050	5565112	3392834	34.67	10.57	1.54	1.02	Trt
03/08/04	0.37	0.173	85808492	74108989	1994.14	798.79	3.30	2.90	Trt

03/15/04	0.09	0.070	21507982	33414365	120.60	145.73	2.08	2.16	Trt
03/22/04	0.11	0.069	9080715	14931847	59.41	64.19	1.77	1.81	Trt
03/29/04	0.15	0.081	35363158	12603295	326.08	63.60	2.51	1.80	Trt
04/05/04	0.14	0.055	25836330	47045601	225.36	161.21	2.35	2.21	Trt
04/12/04	0.08	0.046	9348448	23791810	48.93	68.19	1.69	1.83	Trt
04/19/04	0.07	0.058	8746049	9191489	39.78	33.21	1.60	1.52	Trt
04/26/04	0.11	0.090	77397218	71016978	549.73	398.22	2.74	2.60	Trt
05/03/04	0.15	0.062	71417850	43659648	685.24	168.65	2.84	2.23	Trt
05/10/04	0.09	0.058	40583949	28070282	230.10	101.44	2.36	2.01	Trt
05/17/04	0.203	0.050	27781463	8076597	351.37	25.16	2.55	1.40	Trt
05/24/04	0.145	0.060	9881755	40016842	89.27	149.59	1.95	2.17	Trt
06/01/04	0.110	0.452	2999338	11763735	20.56	331.28	1.31	2.52	Trt
06/07/04	0.098	0.057	2681692	3556817	16.37	12.63	1.21	1.10	Trt
06/14/04	0.110	0.063	3225357	4001820	22.10	15.71	1.34	1.20	Trt
06/21/04	0.098	0.049	3138480	4712271	19.16	14.39	1.28	1.16	Trt
06/28/04	0.109	0.065	3172479	6916280	21.54	28.01	1.33	1.45	Trt
07/06/04	0.5	0.286	65862331	37190584	3960.09	662.70	3.60	2.82	Trt
07/12/04	0.498	0.062	29106480	49077139	903.10	189.58	2.96	2.28	Trt
07/19/04	0.134	0.067	5268776	33239678	43.99	138.75	1.64	2.14	Trt
07/26/04	0.126	0.093	9169959	9201826	71.99	53.32	1.86	1.73	Trt
08/02/04	0.091	0.080	11143034	6529208	63.18	32.54	1.80	1.51	Trt
08/09/04	0.247	0.065	7028097	4602528	108.16	18.64	2.03	1.27	Trt
08/16/04	0.154	0.05	6046409	3325152	58.01	10.36	1.76	1.02	Trt
08/23/04	0.100	0.073	6123487	5052499	38.15	22.98	1.58	1.36	Trt
08/30/04	0.105	0.086	5934854	3628800	38.83	19.44	1.59	1.29	Trt
09/06/04	0.079	0.054	4841611	2937371	23.83	9.88	1.38	0.99	Trt
09/13/04	0.183	0.048	2512084	1984781	28.64	5.94	1.46	0.77	Trt
09/20/04	0.117	0.127	2786194	1890000	20.31	14.95	1.31	1.17	Trt
09/27/04	0.090	0.065	2363684	2073450	13.25	8.40	1.12	0.92	Trt
10/04/04	0.082	0.061	1873090	2370000	9.57	9.01	0.98	0.95	Trt
10/11/04	0.080	0.055	2253762	2339616	11.23	8.02	1.05	0.90	Trt
10/18/04	0.095	0.050	2592518	3078719	15.34	9.59	1.19	0.98	Trt
10/25/04	0.075	0.048	3079888	2655072	14.39	7.94	1.16	0.90	Trt
11/02/04	0.27	0.045	27584854	58387081	464.03	163.70	2.67	2.21	Trt
11/08/04	0.122	0.029	14114098	33213197	107.28	60.01	2.03	1.78	Trt
11/15/04	0.096	0.038	3333832	18025459	19.94	42.68	1.30	1.63	Trt
11/22/04	0.790	0.053	9519176	13030820	468.54	43.03	2.67	1.63	Trt
11/29/04	0.075	0.037	19960695	12568413	93.27	28.97	1.97	1.46	Trt
12/06/04	0.148	0.046	24559767	22284962	226.47	63.87	2.36	1.81	Trt
12/13/04	0.120	0.039	32596585	33671226	243.71	81.82	2.39	1.91	Trt
12/20/04	0.098	0.045	27384152	39126826	167.20	109.70	2.22	2.04	Trt
12/27/04	0.107	0.035	12298976	11051163	81.61	24.10	1.91	1.38	Trt
01/03/05	0.115	0.05	4546457	6531840	32.58	20.35	1.51	1.31	Trt
01/10/05	0.35	0.233	54410018	131829425	1169.54	1913.75	3.07	3.28	Trt
01/18/05	0.260	0.052	28515350	48299450	461.92	156.48	2.66	2.19	Trt
01/24/05	0.085	0.046	19555141	36092903	103.56	103.44	2.02	2.01	Trt
01/31/05	0.093	0.037	16866932	6313780	97.73	14.55	1.99	1.16	Trt

02/07/05	0.089	0.047	12546052	4729375	69.57	13.85	1.84	1.14	Trt
02/14/05	0.06	0.070	13342130	7412151	53.20	32.33	1.73	1.51	Trt
02/22/05	0.053	0.013	8576489	11793946	28.32	9.55	1.45	0.98	Trt
02/28/05	0.063	0.050	11863495	8006675	46.57	24.94	1.67	1.40	Trt
03/07/05	0.093	0.029	8926362	13026120	51.72	23.54	1.71	1.37	Trt
03/14/05	0.131	0.03	6511367	9676800	53.14	18.09	1.73	1.26	Trt
03/21/05	0.075	0.037	5046561	4580475	23.58	10.56	1.37	1.02	Trt
03/28/05	0.076	0.034	5887496	4415747	27.88	9.35	1.45	0.97	Trt
04/04/05	0.056	0.016	8710490	27457920	30.39	27.37	1.48	1.44	Trt
04/11/05	0.049	0.006	20133826	33847438	61.47	12.65	1.79	1.10	Trt
04/18/05	0.071	0.017	15777174	22949956	69.79	24.31	1.84	1.39	Trt
04/25/05	0.131	0.023	27384152	8248262	223.50	11.82	2.35	1.07	Trt
05/02/05	0.083	0.021	13614375	5937926	70.40	7.77	1.85	0.89	Trt
05/09/05	0.097	0.029	4546457	5537549	27.48	10.01	1.44	1.00	Trt
05/16/05	0.074	0.025	55488275	5108141	255.83	7.96	2.41	0.90	Trt
05/23/05	0.041	**0.004**	34922141	5241197	89.21	1.15	1.95	0.06	Trt
05/30/05	0.12	0.010	7987473	5416243	61.71	3.37	1.79	0.53	Trt
06/06/05	0.155	0.026	23041312	3509568	222.51	5.69	2.35	0.75	Trt
06/13/05	0.063	0.026	16866932	5606496	66.21	9.08	1.82	0.96	Trt
06/20/05	0.036	0.011	12546052	4775501	28.14	3.27	1.45	0.51	Trt
06/27/05	0.086	0.364	7504428	2949610	40.21	66.89	1.60	1.83	Trt
07/05/05	0.109	**0.011**	22248357	3366144	151.09	2.22	2.18	0.35	Trt
07/11/05	0.048	0.021	7651167	1935706	22.88	2.53	1.36	0.40	Trt
07/18/05	0.063	0.039	3949169	2313965	15.50	5.62	1.19	0.75	Trt
07/25/05	0.066	0.007	2368906	2883476	9.74	1.26	0.99	0.10	Trt
08/02/05	0.079	0.026	2290409	3234055	11.27	5.24	1.05	0.72	Trt
08/08/05	0.068	0.028	1263764	2059233	5.35	3.59	0.73	0.56	Trt
08/15/05	0.123	0.009	752575	2189210	5.77	1.23	0.76	0.09	Trt

Table B-2. Log Base 10 Data for Beaty Creek and Little Saline Creek.

Log10 BC T-P Load (kg)	Log10 LS T-P Load (kg)	Period Cal=0 Trt=1	Log10 LS T-P * Period
1.00	0.20	0	0.00
1.18	0.61	0	0.00
1.13	0.41	0	0.00
0.89	0.25	0	0.00
0.85	0.34	0	0.00
1.04	0.35	0	0.00
1.16	0.27	0	0.00
0.72	1.23	0	0.00
0.75	0.24	0	0.00
0.80	0.12	0	0.00

0.70	-0.07	0	0.00
0.61	0.39	0	0.00
0.95	0.17	0	0.00
1.78	0.45	0	0.00
1.63	1.00	0	0.00
1.31	0.76	0	0.00
1.60	0.33	0	0.00
0.96	0.20	0	0.00
1.20	0.46	0	0.00
1.05	0.38	0	0.00
0.78	0.32	0	0.00
0.76	0.13	0	0.00
0.56	0.00	0	0.00
0.61	0.14	0	0.00
0.73	0.50	0	0.00
1.38	0.79	0	0.00
1.08	0.17	0	0.00
1.26	0.07	0	0.00
1.56	0.65	0	0.00
1.22	0.82	0	0.00
1.31	1.07	0	0.00
1.53	0.61	0	0.00
1.32	0.71	0	0.00
0.83	0.61	0	0.00
0.78	0.64	0	0.00
1.50	1.68	0	0.00
1.74	1.66	0	0.00
1.51	0.76	0	0.00
1.23	1.71	0	0.00
1.69	1.40	0	0.00
1.31	0.83	0	0.00
2.52	2.15	0	0.00
2.50	2.26	0	0.00
2.14	1.62	0	0.00
1.52	1.22	0	0.00
1.53	0.69	0	0.00
1.33	0.68	0	0.00
2.70	1.33	0	0.00
1.58	0.87	0	0.00
1.31	0.74	0	0.00
1.19	0.52	0	0.00
1.03	0.40	0	0.00
1.41	0.31	0	0.00
0.73	0.10	0	0.00
1.01	0.22	0	0.00
1.08	-0.18	0	0.00
1.53	0.51	0	0.00

0.86	0.10	0	0.00
0.75	-0.38	0	0.00
0.81	0.00	0	0.00
0.51	-0.08	0	0.00
1.31	-0.08	0	0.00
1.20	0.44	0	0.00
1.33	0.79	0	0.00
1.67	0.78	0	0.00
0.89	0.94	0	0.00
0.91	0.68	0	0.00
0.83	0.54	0	0.00
0.83	0.54	0	0.00
0.91	0.47	0	0.00
0.64	0.20	0	0.00
1.38	0.66	0	0.00
0.92	1.20	0	0.00
1.68	1.62	0	0.00
2.24	1.36	0	0.00
1.45	1.08	0	0.00
1.81	0.94	0	0.00
3.52	2.67	0	0.00
1.65	0.93	0	0.00
1.46	0.85	0	0.00
1.30	0.70	0	0.00
1.14	0.66	0	0.00
0.55	0.37	0	0.00
1.41	0.47	0	0.00
1.36	0.95	0	0.00
1.15	0.45	0	0.00
1.24	0.51	0	0.00
1.27	0.41	0	0.00
1.34	0.46	0	0.00
1.11	0.12	0	0.00
1.01	0.02	0	0.00
1.29	0.10	0	0.00
1.14	0.12	0	0.00
1.17	0.16	0	0.00
1.18	0.45	0	0.00
1.29	0.77	0	0.00
1.03	0.10	0	0.00
1.36	0.71	0	0.00
1.23	0.70	0	0.00
1.17	0.54	0	0.00
0.92	-0.13	0	0.00
0.73	-0.34	0	0.00
0.91	0.22	0	0.00
1.27	1.27	1	1.27

0.89	0.69	1	0.69
1.06	0.56	1	0.56
0.80	0.53	1	0.53
1.00	0.55	1	0.55
0.54	1.04	1	1.04
1.04	0.89	1	0.89
0.81	0.70	1	0.70
1.09	0.82	1	0.82
1.09	0.78	1	0.78
0.86	0.87	1	0.87
0.95	1.09	1	1.09
1.26	2.09	1	2.09
2.16	1.71	1	1.71
1.71	1.60	1	1.60
1.29	1.79	1	1.79
1.50	0.95	1	0.95
1.25	0.97	1	0.97
1.27	1.00	1	1.00
1.20	0.68	1	0.68
2.96	2.56	1	2.56
1.74	1.82	1	1.82
1.43	1.46	1	1.46
2.17	1.46	1	1.46
2.01	1.86	1	1.86
1.35	1.49	1	1.49
1.26	1.18	1	1.18
2.40	2.26	1	2.26
2.49	1.88	1	1.88
2.02	1.66	1	1.66
2.20	1.06	1	1.06
1.61	1.83	1	1.83
0.97	2.18	1	2.18
0.87	0.76	1	0.76
1.00	0.85	1	0.85
0.94	0.81	1	0.81
0.99	1.10	1	1.10
3.25	2.48	1	2.48
2.61	1.93	1	1.93
1.30	1.80	1	1.80
1.51	1.38	1	1.38
1.46	1.17	1	1.17
1.69	0.93	1	0.93
1.42	0.67	1	0.67
1.24	1.02	1	1.02
1.25	0.95	1	0.95
1.03	0.65	1	0.65
1.11	0.43	1	0.43

0.96	0.83	1	0.83
0.78	0.58	1	0.58
0.64	0.61	1	0.61
0.71	0.56	1	0.56
0.84	0.64	1	0.64
0.81	0.56	1	0.56
2.32	1.87	1	1.87
1.69	1.43	1	1.43
0.96	1.29	1	1.29
2.33	1.29	1	1.29
1.63	1.12	1	1.12
2.01	1.46	1	1.46
2.04	1.57	1	1.57
1.88	1.70	1	1.70
1.57	1.04	1	1.04
1.17	0.97	1	0.97
2.72	2.94	1	2.94
2.32	1.85	1	1.85
1.67	1.67	1	1.67
1.65	0.82	1	0.82
1.50	0.80	1	0.80
1.38	1.17	1	1.17
1.11	0.64	1	0.64
1.32	1.05	1	1.05
1.37	1.03	1	1.03
1.38	0.91	1	0.91
1.03	0.68	1	0.68
1.10	0.63	1	0.63
1.14	1.09	1	1.09
1.45	0.76	1	0.76
1.50	1.04	1	1.04
2.01	0.73	1	0.73
1.50	0.55	1	0.55
1.10	0.66	1	0.66
2.06	0.56	1	0.56
1.61	-0.28	1	-0.28
1.45	0.18	1	0.18
2.00	0.41	1	0.41
1.48	0.61	1	0.61
1.11	0.17	1	0.17
1.26	1.48	1	1.48
1.84	0.00	1	0.00
1.02	0.06	1	0.06
0.85	0.41	1	0.41
0.65	-0.24	1	-0.24
0.71	0.38	1	0.38
0.39	0.21	1	0.21

0.42	-0.25	1	-0.25

Table B-3. Percent Reduction in Beaty Creek between Calibration and Treatment Period.

pred log10	obs log10	pred (kg)	obs (kg)	Predicted -observed (kg)
1.68	1.54	47.32	35.01	12.32
1.29	1.20	19.71	15.96	3.75
1.21	1.12	16.06	13.29	2.77
1.19	1.11	15.33	12.74	2.59
1.20	1.12	15.99	13.23	2.76
1.52	1.41	33.39	25.61	7.78
1.42	1.32	26.51	20.83	5.69
1.30	1.21	20.11	16.25	3.86
1.38	1.28	24.09	19.11	4.98
1.35	1.26	22.61	18.06	4.56
1.41	1.31	25.99	20.45	5.53
1.56	1.44	35.92	27.34	8.58
2.22	2.03	165.33	107.45	57.88
1.97	1.81	92.97	64.13	28.84
1.89	1.74	78.51	55.12	23.40
2.02	1.86	105.74	71.97	33.76
1.46	1.35	29.10	22.64	6.46
1.48	1.37	29.92	23.21	6.71
1.50	1.39	31.49	24.30	7.19
1.29	1.20	19.39	15.73	3.66
2.53	2.31	339.72	204.94	134.78
2.04	1.87	110.15	74.66	35.49
1.81	1.66	64.01	45.90	18.12
1.80	1.66	63.62	45.65	17.98
2.07	1.90	117.76	79.27	38.49
1.82	1.68	66.62	47.57	19.05
1.62	1.49	41.38	31.04	10.34
2.33	2.13	214.28	135.58	78.70
2.08	1.91	121.33	81.42	39.91
1.94	1.78	86.66	60.21	26.44
1.54	1.42	34.43	26.32	8.11
2.05	1.88	112.07	75.83	36.24
2.28	2.08	189.71	121.55	68.15
1.34	1.24	21.82	17.49	4.33
1.40	1.30	25.21	19.90	5.30
1.38	1.28	23.78	18.89	4.89
1.57	1.45	36.97	28.05	8.91
2.48	2.26	300.21	183.43	116.77
2.12	1.94	131.10	87.28	43.82
2.03	1.86	106.63	72.52	34.11
1.75	1.61	56.61	41.11	15.50

1.61	1.49	40.83	30.67	10.16
1.45	1.34	28.23	22.03	6.20
1.28	1.19	19.14	15.55	3.59
1.51	1.40	32.43	24.95	7.48
1.46	1.35	29.03	22.59	6.44
1.27	1.18	18.55	15.12	3.43
1.12	1.05	13.24	11.17	2.06
1.39	1.29	24.40	19.33	5.07
1.22	1.14	16.65	13.72	2.93
1.24	1.16	17.44	14.31	3.14
1.21	1.13	16.15	13.35	2.80
1.26	1.17	18.18	14.85	3.33
1.21	1.12	16.05	13.28	2.77
2.08	1.90	118.96	80.00	38.97
1.79	1.64	61.22	44.10	17.12
1.69	1.56	48.85	36.02	12.83
1.69	1.56	49.12	36.20	12.92
1.58	1.46	37.81	28.62	9.18
1.80	1.66	63.80	45.76	18.04
1.88	1.72	75.16	53.00	22.16
1.96	1.80	91.27	63.08	28.19
1.52	1.41	33.46	25.66	7.81
1.48	1.37	29.92	23.21	6.71
2.78	2.54	605.79	344.21	261.57
2.06	1.89	115.46	77.88	37.58
1.94	1.78	87.79	60.92	26.87
1.38	1.28	23.97	19.02	4.94
1.37	1.27	23.19	18.47	4.72
1.61	1.48	40.65	30.55	10.10
1.26	1.17	18.14	14.82	3.32
1.53	1.42	34.24	26.19	8.05
1.52	1.40	32.95	25.30	7.64
1.44	1.34	27.68	21.64	6.03
1.29	1.20	19.38	15.72	3.66
1.25	1.17	17.89	14.63	3.25
1.56	1.44	36.41	27.67	8.73
1.34	1.24	21.85	17.51	4.34
1.53	1.41	33.66	25.79	7.87
1.32	1.23	20.88	16.81	4.07
1.20	1.12	15.82	13.11	2.71
1.27	1.18	18.70	15.23	3.47
1.21	1.12	16.07	13.29	2.78
0.65	0.63	4.48	4.23	0.25
0.96	0.90	9.11	7.99	1.12
1.11	1.04	12.86	10.89	1.97
1.24	1.16	17.54	14.38	3.16
0.95	0.89	8.92	7.85	1.08

1.82	1.67	65.78	47.03	18.75
0.84	0.80	6.91	6.24	0.67
0.88	0.83	7.53	6.74	0.79
1.11	1.03	12.77	10.82	1.95
0.68	0.65	4.74	4.45	0.29
1.09	1.02	12.19	10.37	1.81
0.98	0.92	9.49	8.29	1.20
0.67	0.64	4.66	4.38	0.28
		Predicted		Predicted -observed
		5406.95		1676.92
				(P - O)/ P*100
				31.01

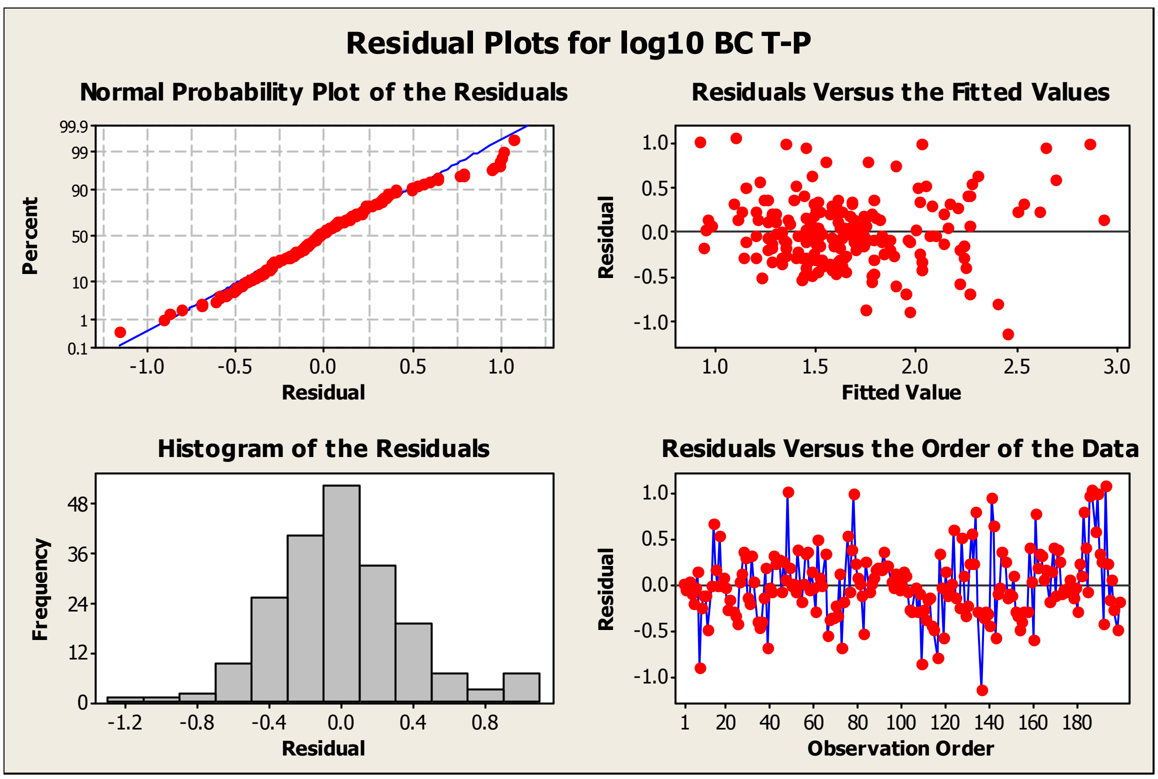


Figure B-1. Residual Plots of Regression Analysis Between Calibration and Treatment Periods in Beaty Creek.

Table B-4. Regression Analysis of slope and intercepts between calibration and treatment periods.

Combined Slope and Intercept Procedure

Regression Analysis: Log10 BC T-P versus Log10 LS T-P, Period Cal=0 Trt=1

```
The regression equation is
Log10 BC T-P Load (kg) = 0.837 + 0.662 Log10 LS T-P Load (kg)
                         - 0.0422 Period Cal=0 Trt=1
                         - 0.0701 Log10 LS T-P * Period


Predictor                   Coef  SE Coef      T      P
Constant                 0.83689  0.05503  15.21  0.000
Log10 LS T-P Load (kg)   0.66217  0.06839   9.68  0.000
Period Cal=0 Trt=1      -0.04222  0.09301  -0.45  0.650
Log10 LS T-P * Period   -0.07013  0.09211  -0.76  0.447


S = 0.373827   R-Sq = 50.3%   R-Sq(adj) = 49.6%


Analysis of Variance

Source           DF       SS      MS      F      P
Regression        3  27.6065  9.2022  65.85  0.000
Residual Error  195  27.2506  0.1397
Total           198  54.8571


Source                  DF   Seq SS
Log10 LS T-P Load (kg)   1  27.1084
Period Cal=0 Trt=1       1   0.4170
Log10 LS T-P * Period    1   0.0810
```

Table B-5. Regression Analysis of slope between calibration and treatment periods.

Slope Procedure

Regression Analysis: Log10 BC T-P versus Log10 LS T-P, Log10 LS T-P

```
The regression equation is
Log10 BC T-P Load (kg) = 0.822 + 0.676 Log10 LS T-P Load (kg)
                         - 0.103 Log10 LS T-P * Period


Predictor                   Coef  SE Coef      T      P
Constant                 0.82211  0.04427  18.57  0.000
Log10 LS T-P Load (kg)   0.67582  0.06131  11.02  0.000
Log10 LS T-P * Period   -0.10321  0.05621  -1.84  0.068


S = 0.373069   R-Sq = 50.3%   R-Sq(adj) = 49.8%
```

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	27.578	13.789	99.07	0.000
Residual Error	196	27.279	0.139		
Total	198	54.857			

Source	DF	Seq SS
Log10 LS T-P Load (kg)	1	27.108
Log10 LS T-P * Period	1	0.469

Table B-6. Regression Analysis of intercepts between calibration and treatment periods.

Intercept Procedure

Regression Analysis: Log10 BC T-P versus Log10 LS T-P, Period Cal=0 Trt=1

The regression equation is
Log10 BC T-P Load (kg) = 0.860 + 0.624 Log10 LS T-P Load (kg)
- 0.0982 Period Cal=0 Trt=1

Predictor	Coef	SE Coef	T	P
Constant	0.86001	0.04585	18.76	0.000
Log10 LS T-P Load (kg)	0.62351	0.04576	13.63	0.000
Period Cal=0 Trt=1	-0.09825	0.05681	-1.73	0.085

S = 0.373426   R-Sq = 50.2%   R-Sq(adj) = 49.7%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	27.525	13.763	98.70	0.000
Residual Error	196	27.332	0.139		
Total	198	54.857			

Source	DF	Seq SS
Log10 LS T-P Load (kg)	1	27.108
Period Cal=0 Trt=1	1	0.417

Table B-7. Best management practices and associated costs implemented over project duration.

	A	B	C	D	E	F	G	H
1	**BMP**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**Totals**
2	Riparian area managemer	$3,695.00	$5,295.00	$9,640.00	$11,446.00	$14,104.08		$44,180.08
3	Well Drilling	$4,199.40	$8,674.90	$3,144.15	$4,599.74	$25,500.37		$46,118.56
4	Freeze-proof tanks		$3,335.45	$2,160.00	$1,316.92	$13,470.31	$640.00	$20,922.68
5	Litter Clean-Out structures		$12,000.00	$4,935.00	$7,609.22	$9,000.00		$33,544.22
6	Pasture planting	$30,173.98	$13,003.86	$13,285.90	$34,373.72	$27,420.48	$2,215.38	$120,473.32
7	Pasture Nutrient Managen	$22,101.80	$23,362.70	$28,078.00	$31,206.50	$29,060.50		$133,809.50
8	Fence	$11,508.65	$14,595.58	$26,104.23	$18,893.48	$82,481.19	$48,746.32	$202,329.45
9	Ponds	$8,026.90	$1,811.20	$6,495.74	$15,328.95	$3,706.50		$35,369.29
10	Freeze-proof tanks/pipelin	$8,031.07	$15,863.15	$9,618.94	$16,127.55	$67,415.39	$6,276.29	$123,332.39
11	Cow shade		$4,200.00					$4,200.00
12	Poultry Waste Utilization	$9,677.84	$13,212.77	$9,496.87	$7,844.32	$8,381.09		$48,612.89
13	Heavy use areas	$12,096.22	$18,150.47	$13,819.64	$24,741.38	$32,663.28	$5,335.27	$106,806.26
14	Waste Storage/Feeding Facility			$6,300.00	$6,300.00	$100,800.00	$22,680.00	$136,080.00
15	Rural Waste Mgt Systems		$5,912.00	$7,578.40	$5,390.40	$13,639.85	$11,260.00	$43,780.65
16								
17	**Grand Totals**	$109,510.86	$139,417.08	$140,656.87	$185,178.18	$427,643.04	$97,153.26	$1,099,559.29

APPENDIX C

Spavinaw Creek

Table C-1. Loadest2 estimated loads and log base 10 values in kg for the calibration and treatment periods in Spavinaw Creek.

Log10 SV T-P (kg)	Log10 LS T-P Load (kg)	Period Cal=0 Trt=1	Log10 LS T-P (kg)* Period
2.11	0.20	0	0.00
2.16	0.61	0	0.00
2.18	0.41	0	0.00
2.12	0.25	0	0.00
2.08	0.34	0	0.00
2.04	0.35	0	0.00
2.03	0.27	0	0.00
2.01	1.23	0	0.00
2.02	0.24	0	0.00
2.06	0.12	0	0.00
2.03	-0.07	0	0.00
2.03	0.39	0	0.00
2.10	0.17	0	0.00
2.21	0.45	0	0.00
2.40	1.00	0	0.00
2.25	0.76	0	0.00
2.10	0.33	0	0.00
2.06	0.20	0	0.00
2.16	0.46	0	0.00
2.09	0.38	0	0.00
2.06	0.32	0	0.00
2.04	0.13	0	0.00
2.04	0.00	0	0.00
2.04	0.14	0	0.00
2.06	0.50	0	0.00
2.14	0.79	0	0.00
2.46	0.17	0	0.00
2.40	0.07	0	0.00
2.28	0.65	0	0.00
2.23	0.82	0	0.00
2.20	1.07	0	0.00

2.18	0.61	0	0.00
2.22	0.71	0	0.00
2.19	0.61	0	0.00
2.26	0.64	0	0.00
2.72	1.68	0	0.00
2.65	1.66	0	0.00
2.31	0.76	0	0.00
2.87	1.71	0	0.00
2.43	1.40	0	0.00
2.25	0.83	0	0.00
3.70	2.15	0	0.00
4.51	2.26	0	0.00
3.26	1.62	0	0.00
2.60	1.22	0	0.00
2.37	0.69	0	0.00
2.31	0.68	0	0.00
2.65	1.33	0	0.00
2.38	0.87	0	0.00
2.17	0.74	0	0.00
2.09	0.52	0	0.00
2.03	0.40	0	0.00
1.98	0.31	0	0.00
1.94	0.10	0	0.00
1.99	0.22	0	0.00
2.25	-0.18	0	0.00
2.28	0.51	0	0.00
2.03	0.10	0	0.00
1.98	-0.38	0	0.00
1.97	0.00	0	0.00
2.01	-0.08	0	0.00
2.05	-0.08	0	0.00
2.47	0.44	0	0.00
2.20	0.79	0	0.00
2.31	0.78	0	0.00
2.30	0.94	0	0.00
2.14	0.68	0	0.00
2.20	0.54	0	0.00
2.23	0.54	0	0.00
2.18	0.47	0	0.00
2.20	0.20	0	0.00
2.44	0.66	0	0.00
2.36	1.20	0	0.00
2.58	1.62	0	0.00
2.73	1.36	0	0.00
2.54	1.08	0	0.00
3.08	0.94	0	0.00
4.23	2.67	0	0.00

3.07	0.93	0	0.00
2.66	0.85	0	0.00
2.51	0.70	0	0.00
2.42	0.66	0	0.00
2.38	0.37	0	0.00
2.34	0.47	0	0.00
2.39	0.95	0	0.00
2.39	0.45	0	0.00
2.30	0.51	0	0.00
2.26	0.41	0	0.00
2.31	0.46	0	0.00
2.31	0.12	0	0.00
2.28	0.02	0	0.00
2.31	0.10	0	0.00
2.21	0.12	0	0.00
2.34	0.16	0	0.00
2.22	0.45	0	0.00
2.12	0.77	0	0.00
2.08	0.10	0	0.00
2.02	0.71	0	0.00
2.03	0.70	0	0.00
1.98	0.54	0	0.00
1.98	-0.13	0	0.00
1.95	-0.34	0	0.00
1.92	0.22	0	0.00
1.90	1.27	1	1.27
1.89	0.69	1	0.69
1.89	0.56	1	0.56
1.84	0.53	1	0.53
1.82	0.55	1	0.55
1.82	1.04	1	1.04
1.79	0.89	1	0.89
1.82	0.70	1	0.70
1.83	0.82	1	0.82
1.80	0.78	1	0.78
1.79	0.87	1	0.87
1.81	1.09	1	1.09
1.83	2.09	1	2.09
2.03	1.71	1	1.71
1.97	1.60	1	1.60
1.83	1.79	1	1.79
1.97	0.95	1	0.95
2.03	0.97	1	0.97
1.97	1.00	1	1.00
2.03	0.68	1	0.68
2.17	2.56	1	2.56
2.21	1.82	1	1.82

2.28	1.46	1	1.46
2.11	1.46	1	1.46
2.11	1.86	1	1.86
2.13	1.49	1	1.49
2.07	1.18	1	1.18
2.04	2.26	1	2.26
3.40	1.88	1	1.88
2.55	1.66	1	1.66
2.33	1.06	1	1.06
2.65	1.83	1	1.83
2.63	2.18	1	2.18
2.37	0.76	1	0.76
2.36	0.85	1	0.85
3.82	0.81	1	0.81
3.36	1.10	1	1.10
2.83	2.48	1	2.48
2.61	1.93	1	1.93
2.37	1.80	1	1.80
2.25	1.38	1	1.38
2.20	1.17	1	1.17
2.16	0.93	1	0.93
2.16	0.67	1	0.67
2.14	1.02	1	1.02
4.50	0.95	1	0.95
2.97	0.65	1	0.65
2.55	0.43	1	0.43
2.39	0.83	1	0.83
2.65	0.58	1	0.58
2.44	0.61	1	0.61
2.26	0.56	1	0.56
2.22	0.64	1	0.64
2.15	0.56	1	0.56
2.06	1.87	1	1.87
2.00	1.43	1	1.43
1.95	1.29	1	1.29
1.90	1.29	1	1.29
1.86	1.12	1	1.12
1.85	1.46	1	1.46
1.85	1.57	1	1.57
1.85	1.70	1	1.70
2.78	1.04	1	1.04
2.69	0.97	1	0.97
2.06	2.94	1	2.94
1.95	1.85	1	1.85
2.24	1.67	1	1.67
2.53	0.82	1	0.82
2.68	0.80	1	0.80

2.19	1.17	1	1.17
2.05	0.64	1	0.64
2.00	1.05	1	1.05
3.85	1.03	1	1.03
3.60	0.91	1	0.91
2.67	0.68	1	0.68
2.39	0.63	1	0.63
2.28	1.09	1	1.09
2.32	0.76	1	0.76
2.29	1.04	1	1.04
2.35	0.73	1	0.73
2.28	0.55	1	0.55
2.26	0.66	1	0.66
2.21	0.56	1	0.56
2.22	-0.28	1	-0.28
2.29	0.18	1	0.18
2.67	0.41	1	0.41
2.43	0.61	1	0.61
2.22	0.17	1	0.17
2.14	1.48	1	1.48
2.08	0.00	1	0.00
2.06	0.06	1	0.06
2.04	0.41	1	0.41
2.10	-0.24	1	-0.24
2.02	0.38	1	0.38
1.99	0.21	1	0.21
2.15	-0.25	1	-0.25

APPENDIX D

Beaty Creek with Spavinaw Creek as Calibration Watershed

Table D-1. Log Base 10 Data for Beaty Creek and Spavinaw Creek in kg.

Log10 BC T-P Load (kg)	Log10 SV T-P (kg)	Period	Log10 SV T-P* Period
1.00	2.11	0	0.00
1.18	2.16	0	0.00
1.13	2.18	0	0.00
0.89	2.12	0	0.00
0.85	2.08	0	0.00
1.04	2.04	0	0.00
1.16	2.03	0	0.00
0.72	2.01	0	0.00
0.75	2.02	0	0.00
0.80	2.06	0	0.00
0.70	2.03	0	0.00
0.61	2.03	0	0.00
0.95	2.10	0	0.00
1.78	2.21	0	0.00
1.63	2.40	0	0.00
1.31	2.25	0	0.00
1.60	2.10	0	0.00
0.96	2.06	0	0.00
1.20	2.16	0	0.00
1.05	2.09	0	0.00
0.78	2.06	0	0.00
0.76	2.04	0	0.00
0.56	2.04	0	0.00
0.61	2.04	0	0.00
0.73	2.06	0	0.00
1.38	2.14	0	0.00
1.08	2.46	0	0.00
1.26	2.40	0	0.00
1.56	2.28	0	0.00
1.22	2.23	0	0.00
1.31	2.20	0	0.00
1.53	2.18	0	0.00
1.32	2.22	0	0.00
0.83	2.19	0	0.00
0.78	2.26	0	0.00
1.50	2.72	0	0.00

1.74	2.65	0	0.00
1.51	2.31	0	0.00
1.23	2.87	0	0.00
1.69	2.43	0	0.00
1.31	2.25	0	0.00
2.52	3.70	0	0.00
2.50	4.51	0	0.00
2.14	3.26	0	0.00
1.52	2.60	0	0.00
1.53	2.37	0	0.00
1.33	2.31	0	0.00
2.70	2.65	0	0.00
1.58	2.38	0	0.00
1.31	2.17	0	0.00
1.19	2.09	0	0.00
1.03	2.03	0	0.00
1.41	1.98	0	0.00
0.73	1.94	0	0.00
1.01	1.99	0	0.00
1.08	2.25	0	0.00
1.53	2.28	0	0.00
0.86	2.03	0	0.00
0.75	1.98	0	0.00
0.81	1.97	0	0.00
0.51	2.01	0	0.00
1.31	2.05	0	0.00
1.20	2.47	0	0.00
1.33	2.20	0	0.00
1.67	2.31	0	0.00
0.89	2.30	0	0.00
0.91	2.14	0	0.00
0.83	2.20	0	0.00
0.83	2.23	0	0.00
0.91	2.18	0	0.00
0.64	2.20	0	0.00
1.38	2.44	0	0.00
0.92	2.36	0	0.00
1.68	2.58	0	0.00
2.24	2.73	0	0.00
1.45	2.54	0	0.00
1.81	3.08	0	0.00
3.52	4.23	0	0.00
1.65	3.07	0	0.00
1.46	2.66	0	0.00
1.30	2.51	0	0.00
1.14	2.42	0	0.00
0.55	2.38	0	0.00

1.41	2.34	0	0.00
1.36	2.39	0	0.00
1.15	2.39	0	0.00
1.24	2.30	0	0.00
1.27	2.26	0	0.00
1.34	2.31	0	0.00
1.11	2.31	0	0.00
1.01	2.28	0	0.00
1.29	2.31	0	0.00
1.14	2.21	0	0.00
1.17	2.34	0	0.00
1.18	2.22	0	0.00
1.29	2.12	0	0.00
1.03	2.08	0	0.00
1.36	2.02	0	0.00
1.23	2.03	0	0.00
1.17	1.98	0	0.00
0.92	1.98	0	0.00
0.73	1.95	0	0.00
0.91	1.92	0	0.00
1.27	1.90	1	1.90
0.89	1.89	1	1.89
1.06	1.89	1	1.89
0.80	1.84	1	1.84
1.00	1.82	1	1.82
0.54	1.82	1	1.82
1.04	1.79	1	1.79
0.81	1.82	1	1.82
1.09	1.83	1	1.83
1.09	1.80	1	1.80
0.86	1.79	1	1.79
0.95	1.81	1	1.81
1.26	1.83	1	1.83
2.16	2.03	1	2.03
1.71	1.97	1	1.97
1.29	1.83	1	1.83
1.50	1.97	1	1.97
1.25	2.03	1	2.03
1.27	1.97	1	1.97
1.20	2.03	1	2.03
2.96	2.17	1	2.17
1.74	2.21	1	2.21
1.43	2.28	1	2.28
2.17	2.11	1	2.11
2.01	2.11	1	2.11
1.35	2.13	1	2.13
1.26	2.07	1	2.07

2.40	2.04	1	2.04
2.49	3.40	1	3.40
2.02	2.55	1	2.55
2.20	2.33	1	2.33
1.61	2.65	1	2.65
0.97	2.63	1	2.63
0.87	2.37	1	2.37
1.00	2.36	1	2.36
0.94	3.82	1	3.82
0.99	3.36	1	3.36
3.25	2.83	1	2.83
2.61	2.61	1	2.61
1.30	2.37	1	2.37
1.51	2.25	1	2.25
1.46	2.20	1	2.20
1.69	2.16	1	2.16
1.42	2.16	1	2.16
1.24	2.14	1	2.14
1.25	4.50	1	4.50
1.03	2.97	1	2.97
1.11	2.55	1	2.55
0.96	2.39	1	2.39
0.78	2.65	1	2.65
0.64	2.44	1	2.44
0.71	2.26	1	2.26
0.84	2.22	1	2.22
0.81	2.15	1	2.15
2.32	2.06	1	2.06
1.69	2.00	1	2.00
0.96	1.95	1	1.95
2.33	1.90	1	1.90
1.63	1.86	1	1.86
2.01	1.85	1	1.85
2.04	1.85	1	1.85
1.88	1.85	1	1.85
1.57	2.78	1	2.78
1.17	2.69	1	2.69
2.72	2.06	1	2.06
2.32	1.95	1	1.95
1.67	2.24	1	2.24
1.65	2.53	1	2.53
1.50	2.68	1	2.68
1.38	2.19	1	2.19
1.11	2.05	1	2.05
1.32	2.00	1	2.00
1.37	3.85	1	3.85
1.38	3.60	1	3.60

1.03	2.67	1	2.67
1.10	2.39	1	2.39
1.14	2.28	1	2.28
1.45	2.32	1	2.32
1.50	2.29	1	2.29
2.01	2.35	1	2.35
1.50	2.28	1	2.28
1.10	2.26	1	2.26
2.06	2.21	1	2.21
1.61	2.22	1	2.22
1.45	2.29	1	2.29
2.00	2.67	1	2.67
1.48	2.43	1	2.43
1.11	2.22	1	2.22
1.26	2.14	1	2.14
1.84	2.08	1	2.08
1.02	2.06	1	2.06
0.85	2.04	1	2.04
0.65	2.10	1	2.10
0.71	2.02	1	2.02
0.39	1.99	1	1.99
0.42	2.15	1	2.15

APPENDIX E

Storm Flows

Table E-1. Storm flows vs. base flows with a break point of 13342135 cubic feet per week.

BCDateActivityStart	BCAccumulated flow (cf)	logBCT-P Load (kg)	logLST-P Load (kg)	storm BC	storm LS	base flow BC	base flow LS
09/07/99	4551568	1.00	0.20			1.00	0.20
09/14/99	8567561	1.18	0.61			1.18	0.61
09/22/99	6859185	1.13	0.41			1.13	0.41
09/28/99	4379438	0.89	0.25			0.89	0.25
10/05/99	4863923	0.85	0.34			0.85	0.34
10/12/99	4663123	1.04	0.35			1.04	0.35
10/19/99	4529256	1.16	0.27			1.16	0.27
10/26/99	4596190	0.72	1.23			0.72	1.23
11/02/99	5131655	0.75	0.24			0.75	0.24
11/09/99	5354766	0.80	0.12			0.80	0.12
11/16/99	4886234	0.70	-0.07			0.70	-0.07
11/22/99	4073458	0.61	0.39			0.61	0.39
11/30/99	7853622	0.95	0.17			0.95	0.17
12/07/99	19366119	1.78	0.45	1.78	0.45		
12/14/99	22467358	1.63	1.00	1.63	1.00		
12/21/99	10820979	1.31	0.76			1.31	0.76
12/29/99	8108605	1.60	0.33			1.60	0.33
01/04/00	5756350	0.96	0.20			0.96	0.20
01/11/00	7050408	1.20	0.46			1.20	0.46
01/18/00	6358764	1.05	0.38			1.05	0.38
01/25/00	6046409	0.78	0.32			0.78	0.32
02/01/00	5845610	0.76	0.13			0.76	0.13
02/07/00	4991399	0.56	0.00			0.56	0.00
02/14/00	5756365	0.61	0.14			0.61	0.14
02/23/00	7946069	0.73	0.50			0.73	0.50
03/01/00	16264880	1.38	0.79	1.38	0.79		
03/06/00	13673578	1.08	0.17	1.08	0.17		
03/13/00	14569239	1.26	0.07	1.26	0.07		
03/20/00	9906225	1.56	0.65			1.56	0.65
03/27/00	8835293	1.22	0.82			1.22	0.82

04/03/00	9103026	1.31	1.07			1.31	1.07
04/10/00	7273518	1.53	0.61			1.53	0.61
04/17/00	9214582	1.32	0.71			1.32	0.71
04/24/00	7496629	0.83	0.61			0.83	0.61
05/01/00	8567561	0.78	0.64			0.78	0.64
05/08/00	21507982	1.50	1.68	1.50	1.68		
05/15/00	27152683	1.74	1.66	1.74	1.66		
05/22/00	10017780	1.51	0.76			1.51	0.76
05/30/00	16370077	1.23	1.71	1.23	1.71		
06/05/00	8338060	1.69	1.40			1.69	1.40
06/12/00	6626497	1.31	0.83			1.31	0.83
06/19/00	29138369	2.52	2.15	2.52	2.15		
06/27/00	45744197	2.50	2.26	2.50	2.26		
07/05/00	33504980	2.14	1.62	2.14	1.62		
07/10/00	9498220	1.52	1.22			1.52	1.22
07/17/00	8857604	1.53	0.69			1.53	0.69
07/24/00	8009784	1.33	0.68			1.33	0.68
07/31/00	24609221	2.70	1.33	2.70	1.33		
08/07/00	11691111	1.58	0.87			1.58	0.87
08/14/00	6001787	1.31	0.74			1.31	0.74
08/21/00	5042411	1.19	0.52			1.19	0.52
08/28/00	4551568	1.03	0.40			1.03	0.40
09/06/00	5220931	1.41	0.31			1.41	0.31
09/11/00	2804898	0.73	0.10			0.73	0.10
09/18/00	4596190	1.01	0.22			1.01	0.22
09/25/00	4908545	1.08	-0.18			1.08	-0.18
10/04/00	6368357	1.53	0.51			1.53	0.51
10/09/00	3091755	0.86	0.10			0.86	0.10
10/16/00	4440012	0.75	-0.38			0.75	-0.38
10/23/00	4573879	0.81	0.00			0.81	0.00
10/30/00	5176278	0.51	-0.08			0.51	-0.08
11/06/00	5466322	1.31	-0.08			1.31	-0.08
11/13/00	7987473	1.20	0.44			1.20	0.44
11/20/00	6202587	1.33	0.79			1.33	0.79
11/27/00	6894230	1.67	0.78			1.67	0.78
12/04/00	7853606	0.89	0.94			0.89	0.94
12/11/00	5890232	0.91	0.68			0.91	0.68
12/18/00	5979476	0.83	0.54			0.83	0.54
12/25/00	6715742	0.83	0.54			0.83	0.54
01/04/01	9370806	0.91	0.47			0.91	0.47
01/08/01	4691762	0.64	0.20			0.64	0.20
01/16/01	15834611	1.38	0.66	1.38	0.66		
01/22/01	8892649	0.92	1.20			0.92	1.20
01/29/01	19879274	1.68	1.62	1.68	1.62		
02/05/01	44488386	2.24	1.36	2.24	1.36		
02/12/01	16599546	1.45	1.08	1.45	1.08		
02/20/01	37202243	1.81	0.94	1.81	0.94		

02/28/01	65122894	3.52	2.67	3.52	2.67		
03/05/01	17131794	1.65	0.93	1.65	0.93		
03/12/01	15238571	1.46	0.85	1.46	0.85		
03/19/01	11646488	1.30	0.70			1.30	0.70
03/26/01	9660803	1.14	0.66			1.14	0.66
04/02/01	8277517	0.55	0.37			0.55	0.37
04/09/01	7518940	1.41	0.47			1.41	0.47
04/16/01	7675118	1.36	0.95			1.36	0.95
04/23/01	8009784	1.15	0.45			1.15	0.45
05/01/01	7573140	1.24	0.51			1.24	0.51
05/07/01	5010523	1.27	0.41			1.27	0.41
05/14/01	5667121	1.34	0.46			1.34	0.46
05/22/01	7063172	1.11	0.12			1.11	0.12
05/29/01	5711743	1.01	0.02			1.01	0.02
06/04/01	5469493	1.29	0.10			1.29	0.10
06/11/01	5220900	1.14	0.12			1.14	0.12
06/18/01	6403387	1.17	0.16			1.17	0.16
06/25/01	5689432	1.18	0.45			1.18	0.45
07/02/01	4774678	1.29	0.77			1.29	0.77
07/09/01	4484634	1.03	0.10			1.03	0.10
07/16/01	4038413	1.36	0.71			1.36	0.71
07/23/01	3815302	1.23	0.70			1.23	0.70
07/30/01	3569880	1.17	0.54			1.17	0.54
08/06/01	3480636	0.92	-0.13			0.92	-0.13
08/27/01	3302148	0.73	-0.34			0.73	-0.34
09/04/01	3799381	0.91	0.22			0.91	0.22
09/08/03	6024098	1.27	1.27			1.27	1.27
09/15/03	2448632	0.89	0.69			0.89	0.69
10/13/03	3971480	1.06	0.56			1.06	0.56
11/10/03	4328457	0.80	0.53			0.80	0.53
11/17/03	4172279	1.00	0.55			1.00	0.55
11/24/03	3469054	0.54	1.04			0.54	1.04
12/01/03	4796989	1.04	0.89			1.04	0.89
12/08/03	2671200	0.81	0.70			0.81	0.70
12/15/03	5756365	1.09	0.82			1.09	0.82
12/22/03	5979476	1.09	0.78			1.09	0.78
12/29/03	2858437	0.86	0.87			0.86	0.87
01/05/04	3780000	0.95	1.09			0.95	1.09
01/12/04	7407385	1.26	2.09			1.26	2.09
01/20/04	21852226	2.16	1.71	2.16	1.71		
01/26/04	18733782	1.71	1.60	1.71	1.60		
02/02/04	8723738	1.29	1.79			1.29	1.79
02/09/04	15531896	1.50	0.95	1.50	0.95		
02/17/04	8093172	1.25	0.97			1.25	0.97
02/24/04	7474318	1.27	1.00			1.27	1.00
03/01/04	5565112	1.20	0.68			1.20	0.68
03/08/04	85808492	2.96	2.56	2.96	2.56		

03/15/04	21507982	1.74	1.82	1.74	1.82		
03/22/04	9080715	1.43	1.46			1.43	1.46
03/29/04	35363158	2.17	1.46	2.17	1.46		
04/05/04	25836330	2.01	1.86	2.01	1.86		
04/12/04	9348448	1.35	1.49			1.35	1.49
04/19/04	8746049	1.26	1.18			1.26	1.18
04/26/04	77397218	2.40	2.26	2.40	2.26		
05/03/04	71417850	2.49	1.88	2.49	1.88		
05/10/04	40583949	2.02	1.66	2.02	1.66		
05/17/04	27781463	2.20	1.06	2.20	1.06		
05/24/04	9881755	1.61	1.83			1.61	1.83
06/01/04	2999338	0.97	2.18			0.97	2.18
06/07/04	2681692	0.87	0.76			0.87	0.76
06/14/04	3225357	1.00	0.85			1.00	0.85
06/21/04	3138480	0.94	0.81			0.94	0.81
06/28/04	3172479	0.99	1.10			0.99	1.10
07/06/04	65862331	3.25	2.48	3.25	2.48		
07/12/04	29106480	2.61	1.93	2.61	1.93		
07/19/04	5268776	1.30	1.80			1.30	1.80
07/26/04	9169959	1.51	1.38			1.51	1.38
08/02/04	11143034	1.46	1.17			1.46	1.17
08/09/04	7028097	1.69	0.93			1.69	0.93
08/16/04	6046409	1.42	0.67			1.42	0.67
08/23/04	6123487	1.24	1.02			1.24	1.02
08/30/04	5934854	1.25	0.95			1.25	0.95
09/06/04	4841611	1.03	0.65			1.03	0.65
09/13/04	2512084	1.11	0.43			1.11	0.43
09/20/04	2786194	0.96	0.83			0.96	0.83
09/27/04	2363684	0.78	0.58			0.78	0.58
10/04/04	1873090	0.64	0.61			0.64	0.61
10/11/04	2253762	0.71	0.56			0.71	0.56
10/18/04	2592518	0.84	0.64			0.84	0.64
10/25/04	3079888	0.81	0.56			0.81	0.56
11/02/04	27584854	2.32	1.87	2.32	1.87		
11/08/04	14114098	1.69	1.43	1.69	1.43		
11/15/04	3333832	0.96	1.29			0.96	1.29
11/22/04	9519176	2.33	1.29			2.33	1.29
11/29/04	19960695	1.63	1.12	1.63	1.12		
12/06/04	24559767	2.01	1.46	2.01	1.46		
12/13/04	32596585	2.04	1.57	2.04	1.57		
12/20/04	27384152	1.88	1.70	1.88	1.70		
12/27/04	12298976	1.57	1.04			1.57	1.04
01/03/05	4546457	1.17	0.97			1.17	0.97
01/10/05	54410018	2.72	2.94	2.72	2.94		
01/18/05	28515350	2.32	1.85	2.32	1.85		
01/24/05	19555141	1.67	1.67	1.67	1.67		
01/31/05	16866932	1.65	0.82	1.65	0.82		

02/07/05	12546052	1.50	0.80				1.50	0.80
02/14/05	13342130	1.38	1.17				1.38	1.17
02/22/05	8576489	1.11	0.64				1.11	0.64
02/28/05	11863495	1.32	1.05				1.32	1.05
03/07/05	8926362	1.37	1.03				1.37	1.03
03/14/05	6511367	1.38	0.91				1.38	0.91
03/21/05	5046561	1.03	0.68				1.03	0.68
03/28/05	5887496	1.10	0.63				1.10	0.63
04/04/05	8710490	1.14	1.09				1.14	1.09
04/11/05	20133826	1.45	0.76	1.45	0.76			
04/18/05	15777174	1.50	1.04	1.50	1.04			
04/25/05	27384152	2.01	0.73	2.01	0.73			
05/02/05	13614375	1.50	0.55	1.50	0.55			
05/09/05	4546457	1.10	0.66				1.10	0.66
05/16/05	55488275	2.06	0.56	2.06	0.56			
05/23/05	34922141	1.61	-0.28	1.61	-0.28			
05/30/05	7987473	1.45	0.18				1.45	0.18
06/06/05	23041312	2.00	0.41	2.00	0.41			
06/13/05	16866932	1.48	0.61	1.48	0.61			
06/20/05	12546052	1.11	0.17				1.11	0.17
06/27/05	7504428	1.26	1.48				1.26	1.48
07/05/05	22248357	1.84	0.00	1.84	0.00			
07/11/05	7651167	1.02	0.06				1.02	0.06
07/18/05	3949169	0.85	0.41				0.85	0.41
07/25/05	2368906	0.65	-0.24				0.65	-0.24
08/02/05	2290409	0.71	0.38				0.71	0.38
08/08/05	1263764	0.39	0.21				0.39	0.21
08/15/05	752575	0.42	-0.25				0.42	-0.25

VITA

Andrew Stolfus Lyon

Candidate for the degree of

Masters of Science

Thesis: PAIRED WATERSHED ANALYSIS TO EVALUATE PHOSPHORUS IN SPAVINAW AND BEATY CREEKS, OKLAHOMA

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